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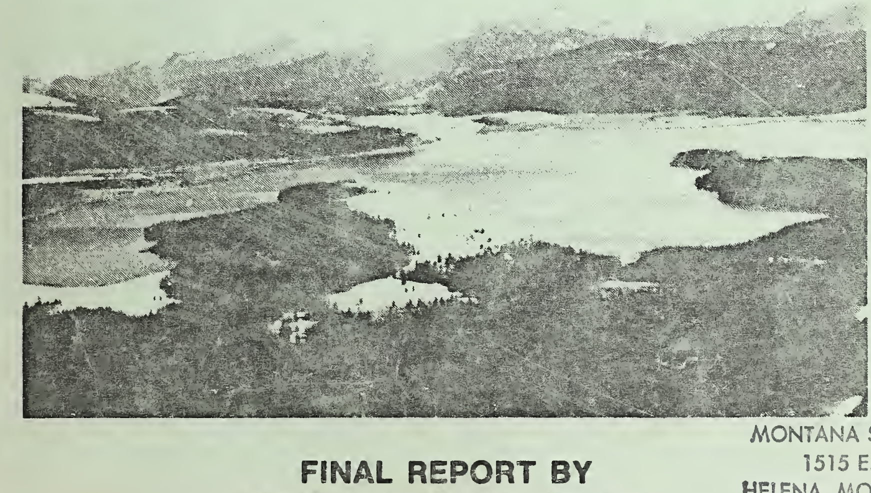

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FINAL REPORT BY
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ACKNOWLEDGEMENT

The Georgetown Lake Clean Lakes Project owes its success in establishing a cooperative lake management plan to the support and cooperation of the people of Granite and Deer Lodge Counties. They have recognized the importance of the resource represented by Georgetown Lake and, over the years, have taken action to insure that the unique natural and esthetic qualities present in the area are preserved.

Special recognition is due the Steering Committee, who devoted long hours to oversee the project and make decisions regarding management alternatives. Many other individuals participated in the dye study and other project activities. The cooperation of the Granite and Deer Lodge County Commissioners and County Planning Boards, U. S. Forest Service, Anaconda Mineral Company and the Montana Power Company was also vital to the development of a cooperative management plan. Critical technical assistance was provided by members of the Technical Advisory Committee and personnel of the Montana Departments of Natural Resources, Health and Environmental Sciences, and Fish, Wildlife and Parks.

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GEORGETOWN LAKE CLEAN LAKES PROJECT

PHASE I

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GLOSSARY OF LAKE AND WATERSHED MANAGEMENT TERMS

Aeration: A process in which water is treated with air or other gases, usually oxygen. In lake restoration, aeration is used to prevent anaerobic condition or to provide artificial destratification.

Algal bloom: A high concentration of a specific algal species in a water body, usually caused by nutrient enrichment.

Algicide: A chemical highly toxic to algae.

Alkalinity: A quantitative measure of water's capacity to neutralize acids. Alkalinity results from the presence of bicarbonates, carbonates, hydroxides, salts, and occasionally of borates, silicates, and phosphates. Numerically, it is expressed as the concentration of calcium carbonate that has an equivalent capacity to neutralize strong acids.

Allochthonous: Describes organic matter produced outside of a specific stream or lake system.

Alluvial: Pertaining to sediments gradually deposited by moving water.

Artificial destratification: The process of inducing water currents in a lake to produce partial or total vertical circulation.

Artificial recharge: The addition of water to the groundwater reservoir by activities of man, such as irrigation or induced infiltration.

Assimilation: The absorption and conversion of nutritive elements into protoplasm.

Autochthon: Any organic matter indigenous to a specific stream or lake.

Autotrophic: The ability to synthesize organic matter from inorganic substances.

Background loading of concentration: The concentration of a chemical constituent arising from natural sources.

Base flow: Stream discharge due to groundwater flow.

Benthic oxygen demand: Oxygen demand exerted from the bottom of a stream or lake, usually by biochemical oxidation of organic material in the sediments.

Benthos: Organisms living on or in the bottom of a body of water.

Best management practices: Practices, either structural or non-structural, which are used to control nonpoint source pollution.

Bioassay: The use of living organisms to determine the biological effect of some substance, factor, or condition.

Biochemical oxidation: The process by which bacteria and other microorganisms break down organic material and remove organic matter from solution.

Biochemical oxygen demand (BOD), biological oxygen demand: The amount of oxygen used by aerobic organisms to decompose organic material. Provides an indirect measure of the concentration of biologically degradable material present in water or wastewater.

Biological control: A method of controlling pest organisms by introduced or naturally occurring predatory organisms, sterilization, inhibiting hormones, or other nonmechanical or nonchemical means.

Biological magnification, biomagnification: An increase in concentration of a substance along succeeding steps in a food chain.

Biomass: The total mass of living organisms in a particular volume or area.

Biota: All living matter in a particular region.

Blue-green algae: The phylum Cyanophyta, characterized by the presence of blue pigment in addition to green chlorophyll.

Catch basin: A collection chamber usually built at the curb line of a street, designed to admit surface water to a sewer or subdrain and to retain matter that would block the sewer.

Catchment: Surface drainage area.

Chemical control: A method of controlling pest organisms through exposure to specific toxic chemicals.

Chlorophyll: Green pigment in plants and algae necessary for photosynthesis.

Circulation period: The interval of time in which the thermal stratification of a lake is destroyed, resulting in the mixing of the entire water body.

Coagulation: The aggregation of colloidal particles, often induced by chemicals such as lime or alum.

Coliform bacteria: Nonpathogenic organisms considered a good indicator of pathogenic bacterial pollution.

Colorimetry: The technique used to infer the concentration of a dissolved substance in solution by comparison of its color intensity with that of a solution of known concentration.

Combined sewer: A sewer receiving both stormwater runoff and sewage.

Compensation point: The depth of water at which oxygen production by photosynthesis and respiration by plants and animals are at equilibrium due to light intensity.

Cover crop: A close-growing crop grown primarily for the purpose of protecting and improving soil between periods of permanent vegetation.

Crustacea: Aquatic animals with a rigid outer covering, jointed appendages, and gills.

Culture: A growth of microorganisms in an artificial medium.

Denitrification: Reduction of nitrates to nitrites or to elemental nitrogen by bacterial action.

Depression storage: Water retained in surface depressions when precipitation intensity is greater than infiltration capacity.

Design storm: A rainfall pattern of specified amount, intensity, duration, and frequency that is used as a basis for design.

Detention: Managing stormwater runoff or sewer flows through temporary holding and controlled release.

Detritus: Finely divided material of organic or inorganic origin.

Diatoms: Organisms belonging to the group Bacillariophyceae, characterized by the presence of silica in its cell walls.

Dilution: A lake restorative measure aimed at reducing nutrient levels within a water body by the replacement of nutrient-rich waters with nutrient-poor waters.

Discharge: A volume of fluid passing a point per unit time, commonly expressed as cubic meters per second.

Dissolved oxygen (DO): The quantity of oxygen present in water in a dissolved state, usually expressed as milligrams per liter of water, or as a percent of saturation at a specific temperature.

Dissolved solids (DS): The total amount of dissolved material, organic and inorganic, contained in water or wastes.

Diversion: A channel or berm constructed across or at the bottom of a slope for the purpose of intercepting surface runoff.

Drainage basin, watershed, drainage area: A geographical area where surface runoff from streams and other natural watercourses is carried by a single drainage system to a common outlet.

Dry weather flow: The combination of sanitary sewage and industrial and commercial wastes normally found in the sanitary sewers during the dry weather season of the year; or, flow in streams during dry seasons.

Dystrophic lakes: Brown-water lakes with a low lime content and a high humus content, often severely lacking nutrients.

Enrichment: The addition to or accumulation of plant nutrients in water.

Epilimnion: The upper, circulating layer of a thermally stratified lake.

Erosion: The process by which the soils of the earth's crust are worn away and carried from one place to another by weathering, corrosion, solution, and transportation.

Eutrophication: A natural enrichment process of a lake, which may be accelerated by man's activities. Usually manifested by one or more of the following characteristics: (a) excessive biomass accumulations of primary producers; (b) rapid organic and/or inorganic sedimentation and shallowing; or (c) seasonal and/or diurnal dissolved oxygen deficiencies.

Fecal streptococcus: A group of bacteria normally present in large numbers in the intestinal tracts of humans and other warm-blooded animals.

First flush: The first, and generally most polluted, portion of runoff generated by rainfall.

Flocculation: The process by which suspended particles collide and combine into larger particles or floccules and settle out of solution.

Gabion: A rectangular or cylindrical wire mesh cage (a chicken wire basket) filled with rock and used to protect against erosion.

Gaging station: A selected section of a stream channel equipped with a gage, recorder, and/or other facilities for determining stream discharge.

Grassed waterway: A natural or constructed waterway covered with erosion-resistant grasses, used to conduct surface water from an area at a reduced flow rate.

Green algae: Algae characterized by the presence of photosynthetic pigments similar in color to those of the higher green plants.

Heavy metals: Metals of high specific gravity, including cadmium, chromium, cobalt, copper, lead, mercury. They are toxic to many organisms even in low concentrations.

Hydrograph: A continuous graph showing the properties of stream flow with respect to time.

Hydrologic cycle: The movement of water from the oceans to the atmosphere and back to the sea. Many subcycles exist including precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration.

Hypolimnion: The lower, non-circulating layer of a thermally stratified lake.

Intermittent stream: A stream or portion of a stream that flows only when replenished by frequent precipitation.

Irrigation return flow: Irrigation water which is not consumed in evaporation or plant growth, and which returns to a surface stream or groundwater reservoir.

Leaching: Removal of the more soluble materials from the soil by percolating waters.

Limiting nutrient: The substance that is limiting to biological growth due to its short supply with respect to other substances necessary for the growth of an organism.

Littoral: The region along the shore of a body of water.

Macrophytes: Large vascular, aquatic plants which are either rooted or floating.

Mesotrophic lake: A trophic condition between an oligotrophic and an eutrophic water body.

Metalimnion: The middle layer of a thermally stratified lake in which temperature rapidly decreases with depth.

Most probable number (MPN): A statistical indication of the number of bacteria present in a given volume (usually 100 ml).

Nannoplankton: Those organisms suspended in open water which because of their small size, cannot be collected by nets (usually smaller than approximately 25 microns).

Nitrification: The biochemical oxidation process by which ammonia is changed first to nitrates and then to nitrites by bacterial action.

Nitrogen, available: Includes ammonium, nitrate ions, ammonia, and certain simple amines readily available for plant growth.

Nitrogen cycle: The sequence of biochemical changes in which atmospheric nitrogen is "fixed," then used by a living organism, liberated upon the death and decomposition of the organism, and reduced to its original state.

Nitrogen fixation: The biological process of removing elemental nitrogen from the atmosphere and incorporating it into organic compounds.

Nitrogen, organic: Nitrogen components of biological origin such as amino acids, proteins, and peptides.

Nonpoint source: Nonpoint source pollutants are not traceable to a discrete origin, but generally result from land runoff, precipitation, drainage, or seepage.

Nutrient, available: That portion of an element or compound that can be readily absorbed and assimilated by growing plants.

Nutrient budget: An analysis of the nutrients entering a lake, discharging from the lake, and accumulating in the lake (e.g., input minus output = accumulation).

Nutrient inactivation: The process of rendering nutrients inactive by one of three methods: (1) Changing the form of a nutrient to make it unavailable to plants, (2) removing the nutrient from the photic zone, or (3) preventing the release or recycling of potentially available nutrients within a lake.

Oligotrophic lake: A lake with a small supply of nutrients, and consequently a low level of primary production. Oligotrophic lakes are often characterized by a high level of species diversification.

Orthophosphate: See phosphorus, available.

Outfall: The point where wastewater or drainage discharges from a sewer to a receiving body of water.

Overturn, turnovers: The complete mixing of a previously thermally stratified lake. This occurs in the spring and fall when water temperatures in the lake are uniform.

Oxygen deficit: The difference between observed oxygen concentrations and the amount that would be present at 100 percent saturation at a specific temperature.

Peak discharge: The maximum instantaneous flow from a given storm condition at a specific location.

Percolation test: A test used to determine the rate of percolation or seepage of water through natural soils. The percolation rate is expressed as time in minutes for a 1-inch fall of water in a test hold and is used to determine the acceptability of a site for treatment of domestic wastes by a septic system.

Perennial stream: A stream that maintains water in its channel throughout the year.

Periphyton: Microorganisms that are attached to or growing on submerged surfaces in a waterway.

Phosphorus, available: Phosphorus which is readily available for plant growth. Usually in the form of soluble orthophosphates.

Phosphorus, total (TP): All of the phosphorus present in a sample regardless of form. Usually measured by the persulfate digestion procedure.

Photic zone: The upper layer in a lake where sufficient light is available for photosynthesis.

Photosynthesis: The process occurring in green plants in which light energy is used to convert inorganic compounds to carbohydrates. In this process, carbon dioxide is consumed and oxygen is released.

Phytoplankton: Plant microorganisms, such as algae, living unattached in the water.

Plankton: Unattached aquatic microorganisms which drift passively through water.

Point source: A discreet pollutant discharge such as a pipe, ditch, channel, or concentrated animal feeding operation.

Population equivalent: An expression of the amount of a given waste load in terms of the size of human population that would contribute the same amount of biochemical oxygen demand (BOD) per day. A common base is 0.17 pounds (7.72 grams) of 5-day BOD per capita per day.

Primary production: The production of organic matter from light energy and inorganic materials, by autotrophic organisms.

Protozoa: Unicellular animals, including the ciliates and nonchlorophyllous flagellates.

Rainfall intensity: The rate at which rain falls, usually expressed in centimeters per hour.

Rational method: A means of computing peak storm drainage runoff (Q) by use of the formula $Q = CIA$, where C is a coefficient describing the physical drainage area, I is the average rainfall intensity, and A is the size of the drainage area.

Raw water: A water supply which is available for use but which has not yet been treated or purified.

Recurrence interval: The anticipated period in years that will elapse, based on average probability of storms in the design region, before a storm of a given intensity and/or total volume will recur; thus, a 10-year storm can be expected to occur on the average once every 10 years. Sewers are generally designed for a specific design storm frequency.

Riprap: Broken rock, cobbles, or boulders placed on earth surfaces, such as the face of a dam or the bank of a stream, for protection against the action of water (waves).

Saprophytic: Pertaining to those organisms that live on dead or decaying organic matter.

Scouring: The clearing and digging action of flowing water, especially the downward erosion caused by stream water in sweeping away mud and silt, usually during a flood.

Secchi depth: A measure of optical water clarity as determined by lowering a weighted Secchi disk into a water body to the point where it is no longer visible.

Sediment basin: A structure designed to slow the velocity of runoff water and facilitate the settling and retention of sediment and debris.

Sediment delivery ratio: The fraction of soil eroded from upland sources that reaches a continuous stream channel or storage reservoir.

Sediment discharge: The quantity of sediment, expressed as a dry weight or volume, transported through a stream cross-section in a given time. Sediment discharge consists of both suspended load and bedload.

Septic: A putrefactive condition produced by anaerobic decomposition of organic wastes, usually accompanied by production of malodorous gases.

Standing crop: The biomass present in a body of water at a particular time.

Sub-basin: A physical division of a larger basin, associated with one reach of the storm drainage system.

Substrate: The substance or base upon which an organism grows.

Suspended solids: Refers to the particulate matter in a sample, including the material that settles readily as well as the material that remains dispersed.

Swale: An elongated depression in the land surface that is at least seasonally wet, is usually heavily vegetated, and is normally without flowing water. Swales conduct stormwater into primary drainage channels and provide some groundwater recharge.

Terrace: An embankment or combination of an embankment and channel built across a slope to control erosion by diverting or storing surface runoff instead of permitting it to flow uninterrupted down the slope.

Thermal stratification: The layering of water bodies due to temperature-induced density differences.

Thermocline: See metalimnion.

Tile drainage: Land drainage by means of a series of tile lines laid at a specified depth and grade.

Total solids: The solids in water, sewage, or other liquids, including the dissolved, filterable, and nonfilterable solids. The residue left when a sample is evaporated and dried at a specified temperature.

Trace elements: Those elements which are needed in low concentrations for the growth of an organism.

Trophic condition: A relative description of a lake's biological productivity. The range of trophic conditions is characterized by the terms oligotrophic for the least biologically productive, to eutrophic for the most biologically productive.

Turbidity: A measure of the cloudiness of a liquid. Turbidity provides an indirect measure of the suspended solids concentration in water.

Urban runoff: Surface runoff from an urban drainage area.

Volatile solids: The quantity of solids in water, sewage, or other liquid, which is lost upon ignition at 600° C.

Waste load allocation: The assignment of target pollutant loads to point sources so as to achieve water quality standards in a stream segment in the most effective manner.

Water quality: A term used to describe the chemical, physical, and biological characteristics of water, usually with respect to its suitability for a particular purpose.

Water quality standards: State-enforced standards describing the required physical and chemical properties of water according to its designated uses.

Watershed: See drainage basin.

Weir: Device for measuring or regulating the flow of water.

Zooplankton: Protozoa and other animal microorganisms living unattached in water.

EXECUTIVE SUMMARY

The Georgetown Clean Lakes Project was implemented in September, 1980, as a Phase I Diagnostic/Feasibility Study under the EPA Clean Lakes Program, Section 314 of Public Law 92-500. The primary objectives were to classify Georgetown Lake as to its trophic condition and prepare a management and restoration plan, particularly relative to the impacts of recreational use and development on water quality and excessive growth of aquatic weeds.

Georgetown Lake is classified as a eutrophic reservoir, due primarily to the natural deposits of soil and organic matter on the reservoir bed and the natural water chemistry. The condition is worsened by the shallow average depth and clear water of the reservoir, which renders most of the bottom available for colonization by aquatic weeds. Evidence obtained during the project did not indicate a deterioration in chemical or biological water quality, as shown by concentrations of dissolved oxygen, nitrogen, and phosphorus, the presence of disease-causing bacteria, or changes in the reservoir's phytoplankton. Annual variations in chemical and biological conditions were attributed to natural hydrological and meteorological causes. No evidence was obtained that recreational development or activities have caused a deterioration of water quality in the reservoir, or have affected the distribution or density of aquatic weeds.

Some species of aquatic weeds have increased appreciably over the past 6-8 years, particularly Potamogeton praelongus (big-leaf pondweed), which in some areas has doubled in the extent of the plant canopy and has also extended its distribution, displacing other species. If this growth continues unchecked, big-leaf pondweed will probably increase to completely cover up to 40-50% of the reservoir's total area (1250-1500) acres within 10-20 years. This increase will cause greater problems with recreational use of the reservoir, but probably will not cause a deterioration in conditions for aquatic life. Growth of other species of aquatic weeds appears to be more variable from year to year, depending on hydrological and meteorological conditions, and their distribution and occurrence do not seem to be undergoing major, long-term changes.

A Lake Management Plan was proposed and accepted by the Technical Advisory and Citizens' Advisory Committees. The primary alternative for in-lake management of aquatic weeds involves an over-winter drawdown of up to 4 feet, to be accomplished between late August and April. Specific guidelines and responsibilities were established to minimize the potential for undesirable impacts on water quality, fish, recreational use, and downstream users. Alternative in-lake management methods include mechanical harvesting and chemical treatment of selected areas. Land use and recreational development guidelines were proposed, including a county shoreline protection act, controls on off-road vehicle use, protection of riparian areas, and dust abatement procedures, within the context of local, state, and federal regulations. The establishment of a buffer zone around the reservoir shoreline was recommended, to reduce the

potential for cultural eutrophication and maintain adequate public access. Recommendations were made for the acquisition of conservation easements or public ownership, to insure shoreline access and retain the esthetic qualities of the area.

INTRODUCTION

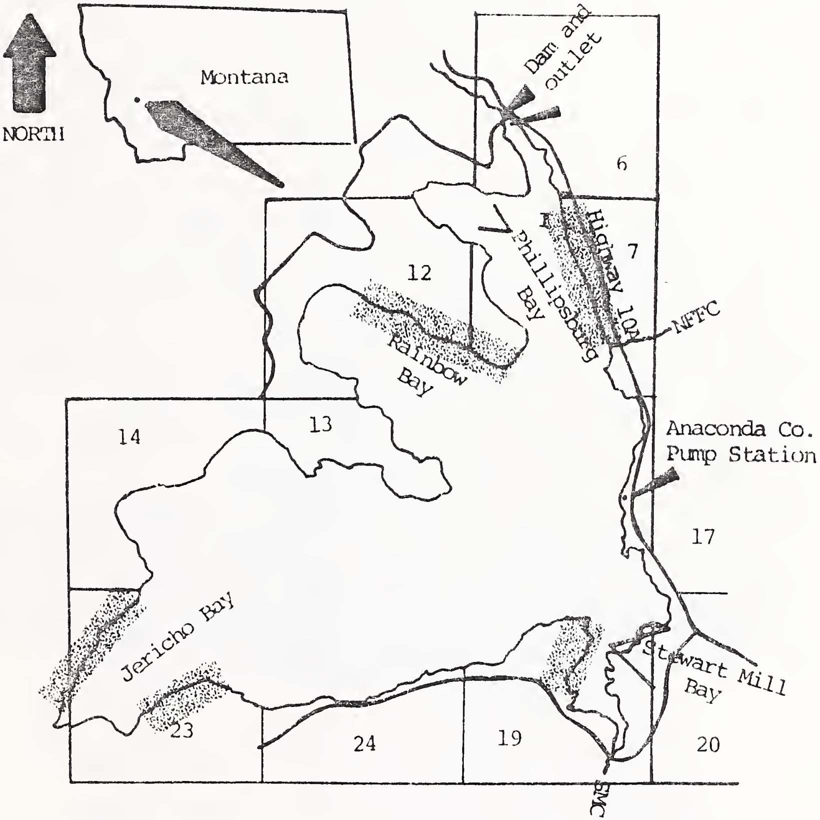
Georgetown Lake is a multiple use reservoir located between Anaconda and Phillipsburg, Montana, on the Phillipsburg Divide (Figure A). U. S. Highway 10A parallels the shoreline for about 5 miles (8 km). Major uses of the reservoir have included water storage for industrial processing, downstream irrigation, power generation, and, as a by-product, recreation. The beautiful natural setting and absence of other similar resources in the area have lent particular importance to the recreational use aspect. Georgetown Lake is one of the most popular and heavily-used aquatic recreational resources in Montana (Lutey, 1973; MDFWP, 1974).

Over time, secondary uses of a resource may assume primary importance under changing economic and social conditions. So it may be with Georgetown Lake. With the closure of the Anaconda Minerals Company smelting facilities in Anaconda and the development of alternative power generation facilities, recreational uses of the reservoir have assumed more importance to the local community, from a standpoint of both personal enjoyment and economic assets. It thus becomes more important to maintain and protect the conditions and qualities which endow the reservoir with its unique esthetic and recreational values.

Recreational activities include fishing, power-boating, sailing, water-skiing, swimming, waterfowl hunting, and in winter, snowmobiling, cross-country skiing, and ice fishing. The reservoir also has a history of periodic algal blooms, occasional winter fish kills of varying severity, and, to some but not all recreationists, excessive aquatic macrophyte growth.

As a result of these problems, coupled with accelerated cultural development in the area and intense public concern about the potential for cultural eutrophication and deterioration of water quality, Georgetown Lake has been the subject of considerable limnological investigation over the past nine years. The work began in 1973. Local concern over the problems stated relative to recreational use of the reservoir and development in the drainage resulted in a research grant from the Department of Interior's Office of Water Research to Montana State University for the investigation of limnological relationships in Georgetown Lake, which continued into 1977. This work has been reported by Geer (1977), Garrison (1976), Foris (1976), Knight et al (1975), Knight (1980), and Garrett (1983). Problems related to fisheries management have been intensively studied since 1958 and documented by the Montana Department of Fish, Wildlife, and Parks. Lutey (1973) reported the results of a preliminary land use and development survey of the Georgetown Lake area. His report documents local concern relative to environmental quality, recreational development, and the value of Georgetown Lake as a recreational and economic resource.

In 1976, the Georgetown Lake Committee, an ad hoc group of concerned citizens, was formed with the assistance of the Headwaters Renewable Resource District. One of the activities of this group was to purchase an aquatic weed cutter to control aquatic weed growths in Georgetown Lake. Toward this purpose, over $5,000 was raised through community activities and private donations. Harvesting was carried



▨ Areas recommended to be considered for establishing conservation easements or public acquisition for access

Figure A. Georgetown Lake Study Area, Deer Lodge and Granite Counties, Montana.

out in several areas, but the project was abandoned when it became apparent that the equipment purchased was not adequate for the task at hand. The harvester employed was too small for the conditions on Georgetown Lake, which is subject to strong winds and waves, did not cut deep enough to adequately remove vegetation, and lacked the capability to collect and transport cut material.

The construction of more summer homes in the area, increasing recreational use in all seasons, and potential for further subdivision and commercial resource development in the drainage basin, coupled with the continued occurrence of nuisance growths of aquatic weeds in the lake itself, intensified concern among lake users and local area residents that water quality in the lake was deteriorating due to man-caused processes, in particular cultural eutrophication. Local questions regarding aquatic weed/water quality/resource development relationships, institutional means of maintaining environmental qaulity through regulatory mechanisms, and management alternatives remained unanswered. In 1976, a perceived increase in the density and distribution of macrophytes brought renewed local concern about water quality/land use/aquatic weed relationships. Through the efforts of the Georgetown Lake Committee, the Montana Department of Natural Resources, and the Montana Water Quality Bureau, EPA funded a Phase I diagnostic/feasibility study of Georgetown Lake. This program was initiated in August, 1980 and continued through August, 1982 as the Georgetown Lake Clean Lakes Project.

Section 314 of the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500) directs the United States Environmental Protection Agency to assist the States in controlling sources of pollution which affects the quality of freshwater lakes through the process of cultural eutrophication and in restoring lakes which have deteriorated in quality due to this process. EPA is fulfilling this mandate through the Clean Lakes Program, which provides technical and financial assistance to the States to:

1. Classify publicly owned freshwater lakes according to trophic condition;
2. Conduct diagnostic studies of specific publicly owned lakes, and develop feasible pollution control and restoration programs for them;
3. Implement lakes restoration and pollution control projects.

Assistance is made available to the States through the EPA Regional Offices in the form of cooperative agreements. Because program funds are limited, and the number of publicly owned lakes with present of potential water quality problems is large, awards must be made selectively. Projects chosen for funding are those which maximize public benefits. Such projects meet three general criteria.

First, projected publics benefits must be significant. A lake to be studied and restored or protected should be one which can provide beneficial uses to a large number of people.

Second, the water quality improvement must be long term, to insure lasting benefits. EPA will not support restoration measures which merely treat symptoms of eutrophication or pollution in a lake. Instead, the agency emphasizes watershed management—a comprehensive effort to identify and eliminate present or potential causes of lake water quality deterioration. Pollution is to be controlled at its source, not in the lake. When pollutant sources are being controlled, however, in-lake restoration techniques to speed recovery are also eligible for funding.

Finally, projects should promote integrated, coordinated water quality management. Other Federal, State, and Local programs can supplement the Clean Lakes Program.

The types of cooperative agreements through which the Clean Lakes Program operates include Phase I, or Diagnostic/Feasibility Studies, and Phase 2, or Implementation Programs. Phase I studies investigate the existing of potential causes of decline in a publicly owned lake's quality, evaluate possible solutions to existing or anticipated pollution problems, and recommend the most feasible program to restore or protecat the quality of the lake. Phase 2 programs implement the recommended actions of Phase 1, and require a 50% non-Federal share in funding, which can often be made up with in-kind services. Inititation of Phase 2 programs is not automatic upon completion of Phase 1, but requires application for funding.

The objectives of the Georgetown Clean Lakes Phase I project were to:

1. Determine the causes of dense aquatic weed growths observed in Georgetown Lake, particularly with regard to cultural influences.
2. Evaluate the effects of aquatic macrophytes on water quallity and recreational use of the lake.
3. Evaluate the probable pattern of aquatic weed growth and distribution in the near future.
4. Evaluate impacts on the lake from recreational use and resource development in the surrounding basin.
5. Development an integrated management plan to improve the conditions in the reservoir relative to weed growth and insure the environmental quality of Georgetown Lake is maintained and the recreational potential preserved.

PROJECT OVERVIEW

Major activities of project personnel included the following

1. Preparation of the Project Work Plan
2. Formation and coordination of Citizen's Input and Action Committees.
3. Primary data collection and analysis.
4. Review and analysis of historical data.
5. Public information
6. Agency coordination
7. Budget Management

In order to "catch up" on latest techniques, methodologies, and on-going projects relative to lake management and restoration, the Project Scientist, Paul Garrett, and state WQB Project Monitor, Dr. Abe Horpestad, attended a week-long, EPA-sponsored symposium on lake management and restoration in September, 1980. This meeting was attended by over 500 professional lake managers, fisheries biologists, and limnologists from all over the world, including Australia, Canada, Great Britain, France, Germany, Holland, Switzerland, and others. Over 100 technical, administrative, and management oriented presentations were given. Also, many informal groups met and discussed common problems in lake management, such as control of weed growth, eutrophication, and management of recreational use and development. The experience proved valuable both from a standpoint of informationa obtained and contacts established for continued consultation and discussion throughout the project.

The Project Work Plan was submitted and approved by the Technical Advisory Committee in October, 1980. Specific objectives were stated and technical approaches outlined for meeting those objectives and additional information requirements. The Work Plan was revised as required to meet additional data needs or in response to input from the Local Steering Committee and Technical Advisory Committee. The major activities defined in the Work Plan included:

1. A study of drainage from septic tanks and other sanitary disposal systems around the reservoir, and an evaluation of their potential impacts on chemical and bacteriological water quality of the reservoir. This was done by two methods. A "dye study",was run in July of 1981. This involved the introduction of fluorescent dye into septic systems around the shoreline and the use of a dye-detection device,a fluorimeter, to detect the entry of dye into the reservoir. Also, a device called a septic leachate detector, which has been widely used in several EPA-sponsored eutrophication/water quality studies, was employed twice in shoreline surveys during the summer of 1981. This activity was monitoredby Dr. Horpestad and Rob Green of the Montana Water Quality Bureau, who observed the detection of actual leachate plumes.

2. Collection and analysis of sediment cores from around the reservoir to determine the rate of sediment deposition, total

depth of sediment accumulations, the amount of phosphorus and nitrogen present in sediments, and the feasibility of dredging as a lake restoration technique. This was carried out from February, 1981-June, 1982.

3. Study of changes in the ecology of aquatic weeds and phytoplankton in the reservoir. This was carried out from the summer of 1981 through the summer of 1982, including the winter. Aerial photography was taken in the summer of 1981 and 1982 to determine changes in extent of weed beds since 1975. The amount of weed present in various areas of the lake in both years was estimated by harvesting small plots with the aid of SCUBA diving equipment. Plants collected were identified to determine the presence of undesirable, non-native species, such as Myriophyllum spicatum, which has caused problems with excessive growth in the midwestern United States. Samples of phytoplankton were collected from June, 1981-September, 1982, to determine changes in phytoplankton communities in response to changes in water quality conditions. The aquatic enclosures which could be seen in Philipsburg Bay and Eccleston's Bay were used to monitor changes in water chemistry due to aquatic weeds, study the interaction between weeds, sediment, and water chemistry, and study the effects of artificially fertilizing the reservoir with nitrogen and phosphorus. The biomass production of weeds and phytoplankton was measured during the summers of 1981 and 1982, to determine changes in total growth and in the balance of growth between algae and weeds since 1974.

4. Methods of suppressing weed growths were also evaluated. Experimental harvesting of some kinds of aquatic weeds was also carried out using a mechanical harvester, to determine the possible long-term effects of mechanical harvesting on regrowth of the weeds. Aquascreen (Registered Trademark) was installed at the Grassy Point Ramp to determine its effectiveness in preventing weed growth.

5. Water samples from the reservoir and adjacent streams were collected and analyzed from June, 1981 through August, 1982, to see if chemical water quality had deteriorated due to cultural eutrophication or resource development in the area. Sampling was carried out through the winter of 1981-1982, and included measurements of oxygen production and consumption by weeds and phytoplankton under the ice to determine the importance of weeds in affecting critical winter dissolved oxygen concentrations, which at times reach values which can be dangerous to fish.

Analyses of these samples enabled the determination of the importance of internal nitrogen and phosphorus supplies (those already present in the reservoir in sediment and weed growths) relative to external supplies coming in from the surrounding drainage. The net balance of nitrogen and phosphorus going into and out of the reservoir was estimated, in order to project allowable nutrient loading in the future. A total of over 4,000 individual chemical analyses were performed.

6. The effects of power boat operation on water chemistry were investigated by operating a 16' outboard in shallow water, then immediately collecting water samples for chemical analyses.

7. Patterns of land and lake use and kinds of land cover were determined by interpretation of aerial photography, review of management agency records (County, State, Forest Service, MPC, AMC), and on-site observations of recreational and residential developments in the area. This information was used to analyze impacts of land use on water quality, and to establish the existence or potential for cultural eutrophication through the estimation of nutrient export from the watershed to streams and the reservoir.

8. Local public attitudes toward lake use, recreational qualities, management policies, resource development, management benefits, and funding were solicited and evaluated through the use of a written questionnaire.

9. The potential impact of the use of Anaconda smelting slag on aquatic environments was evaluated through laboratory studies and analyses of snowmelt and lake and stream water samples.

10. A management plan was developed which addressed the major problems of managing the reservoir as a multiple use resource within the framework of existing state and county regulations and guidelines, and considered potential impacts from continued resource development in the area. The Citizens' Advisory Committee, Local Steering Committee, and Technical Advisory Committee were all closely involved with this process, providing critical input and making key decisions as to which alternatives were most desirable.

CITIZEN COMMITTEES AND PARTICIPATION

Local citizen participation has taken place throughout the project. Citizen activities prior to the cooperative agreement establishing the Georgetown Lake Clean Lakes Project have already been discussed. In November, 1980, the Citizens' Advisory Committee to the Clean Lakes Project met and appointed a local Steering Committee, consisting of seven persons representing various groups of lake users, including landowners, recreationists, and commercial operators. Close coordination was maintained with this group subsequent to its formation. Meetings with project personnel were held throughout the course of the project, progress reviewed, results discussed, budget status evaluated, and local input incorporated into the work schedule. Minutes of the Steering Committee meetings have been distributed to the Citizens' Advisory Committee for review and comment. The Steering Committee has also provided an excellent means for direct input from members of the Citizens' Advisory Committee and public at large. Members of the Local Steering Committee are shown below.

John Naisbitt, Butte	Chairman
Chet Bowler, Butte	Vice-chairman
Ed Cummings, Anaconda	
Jerry Piotrowski, Anaconda	
Floyd Bossard, Butte	
Felix Dauenhower, Georgetown Lake	
Paul Beausoliel, Anaconda	

A local Technical Advisory Committee (TAC), representing local, state and federal management agencies was also formed to advise, review, and assist in the direction of the project. The TAC met as required and reviewed progress and technical reports, suggested modifications to the work plan, and assisted in developing and coordinating the lake management plan. Members of the TAC and their parent organizations are shown below.

Dr. Abe Horpestad, WQB, Helena
Bob Fox, EPA, Helena
Mike Filinger, EPA, Helena
Richard Montgomery, EPA, Helena
Dr. Frank Abercrombie, Montana Bureau of Mines and Technology, Butte
Jim Vashro, Montana Department of Fish, Wildlife, and Parks, Deer Lodge
Wayne Hadley, Montana Department of Fish, Wildlife, and Parks, Deer Lodge
Tom Radonich, Anaconda Minerals Company, Anaconda
Frank Pickett, Montana Power Company, Butte
Chris Vitello, Montana Power Company, Butte
Howard Challinor, U. S. Forest Service, Philipsburg
Mark O'Keefe/Caralee Cheney, Montana Department of Natural Resources

In March, 1981, an action committee was formed to assist with the distribution of fluorescent dye to individual septic systems for tracing of septic tank effluent. In all, over 20 persons assisted with this activity, which was carried out 11-12 July, 1981.

An informal "harvester repair" committee was formed to assist in repairing the mechanical plant harvesting machine, which was then used to make experimental cuts of some aquatic weed communities. Six members of the Citizens' Advisory Committee participated, donating their time and travel expense. Another action committee assisted in the installation of Aquascreen, a weed suppression material, at a test site in the Lake.

PROJECT PERSONNEL

Project Director:	
September 1980-June 1981	Roberta Chandler Director, Deer Lodge County Planning Board Anaconda
July 1981-September 1982	Mike Kahoe Administrative Assistant, Granite County Commissioners Philipsburg
Assistant Project Director:	
September 1980-June 1981	Mike Kahoe
July 1981-September 1982	Milo Manning Director, Deer Lodge County Planning Board Anaconda
Project Scientist:	Paul Garrett Helena
Montana DHES Liason Project Monitor:	Dr. Abe Horpestad Water Quality Bureau Helena
USEPA Liason, Project Supervision:	Bob Fox, Helena EPA Office Mike Filinger, Helena EPA Office Richard Montgomery, Helena EPA Office Ron Eddy, Regional (Denver) EPA Office

SUMMARY OF MAJOR FINDINGS

I. Trophic State

A. Georgetown Lake is a eutrophic reservoir with a high internal nutrient loading capacity. The amount of phosphorus in the sediment is approximately 500-600 times the annual input or output. The amount of nitrogen in the sediment is approximately 400 or 500 times the annual nitrogen input. The potential for algal blooms often is not realized to its fullest extent due to competition for nutrients, or inhibition through some other means, by aquatic macrophytes. Past history documents the occasional occurrence of blue-green algal blooms. Although previous studies indicated that the potentially toxic blue green alga Anabaena flos-aquae formed a major component of the late-summer phytoplankton community, this was not found to be the case in 1981, when the major Anabaena species was identified as circinalis, a non-toxic species.

B. Based on changes in dissolved nitrogen and phosphorus and concentrations of phytoplankton in the water, the reservoir is apparently not becoming more eutrophic, whether due to internal or external causes. Summer phosphorus and nitrogen concentrations during 1981-1982 in the reservoir were about the same or less than those measured in 1973-75. An increase in total nitrogen and total phosphorus occurs in August or early September which is attributed to macrophyte death and decay, and to biological and chemical processes in the sediment. This occurred in all years for which data was available. This "internal loading" is the most most significant source of nutrients to the free water during the ice-free growing season, and carries the potential for producing algal blooms under certain conditions, most likely low water and hot weather. Values of nitrogen and phosphorus during winter (1981-1982) were much less than those measured in 1973-1974 and 1974-1975.

C. Nutrient loading rate (the amount of a nutrient applied to a unit of area over a given time period, such as pounds per acre per year) provides an index to the rate of advancing eutrophication or the importance of external sources in the supply of nutrients in the water. Positive loading rates may indicate advancing eutrophication due to external causes, either natural or man-caused. The annual phosphorus loading rate calculated for June, 1981-May, 1982 was negative (-35 mg/m^2). The net phosphorus budget for June, 1981-May 1982 was 1.5 pounds lost: 1 pound gain, approximately the same value obtained for 1975. The total phosphorus load calculated was approximately 811 kg phosphorus input from all sources. The relative contribution which could be attributed to septic tanks or cultural sources was very small, less than 7% of the total input. The phosphorus exported was calculated to be approximately 1230 kg, based on flow volumes and phosphorus concentrations in the outflow. This indicates that external phosphorus loading is not contributing to a decline in the water quality of Georgetown Lake by eutrophication, and that residential development is not affecting the trophic state of Georgetown Lake at the present.

D. The nitrogen loading rate calculated for June, 1981-May, 1982 was 0.97 g/m^2, which is close to the "safe" limit of 1 g/m^2/yr estimated by Reckhow, et al (1980), but well below the minimum "dangerous" level of 2 g/m^2/yr. Atmospheric sources accounted for 56% of the total; natural hydrologic sources accounted for an additional 34%. Potential for internal loading of nitrogen was also high, as indicated by increases of dissolved ammonia in the experimental enclosures and during winter.

E. The internal phosphorus loading potential from bottom sediments of Georgetown Lake is relatively high, compared to external loading. Enclosure experiments indicated a potential for release of 400 mg P/m^2 sediment (3.6 pounds/acre) under conditions of a total summer macrophyte die-off. The net internal phosphorus loading during the growing season of 1981 (June-October) was at least 35 mg/m^2, based on input/output values and increases in phosphorus concentrations. The safe allowable phosphorus loading rate for Georgetown, as defined by a eutrophication model given by Reckhow, et al (1980), is about 70 mg P/m^2 per year to the water column. The natural internal nutrient loading potential approaches or surpasses this value under appropriate circumstances (Garrett, 1983).

F. Growth of phytoplankton is variable from year to year. June-August, 1981 saw algal densities much lower than those observed in summers of 1973-1975, as indicated by chlorophyll concentrations in the reservoir, which can be used as an index of phytoplankton density. Phytoplankton densities were considerably higher in 1982 from June-September, attaining a maximum chlorophyll concentration of approximately 11 ug per liter. The increase of chlorophyll was not accompanied by an increase in total phosphorus. This result indicates that although phosphorus at some times may limit algal growth, the amount of algal growth also may depend on some other factor or nutrient besides phosphorus, such as nitrogen or carbon.

G. The results of enclosure experiments in 1981 and 1982 indicate that the potential for algal production is very high if the nitrogen and phosphorus in sediments are made available to the algae. In 1982, enclosure experiments with fertilization of nitrogen and phosphorus produced a noticeable increase in algal growth, which was accompanied by a slight increase in macrophyte growth. Algal concentrations in the fertilized enclosure in 1982 did not exceed values obtained near the dam, which indicates that conditions for phytoplankton growth may vary between different locations in the reservoir. This also indicates that small increases in dissolved nutrients in the water, such as would be caused by macrophyte decay due to limited harvesting or herbicide application under non-confined conditions, would not cause a deterioration of water quality due to excessive algal growth. The nutrients released under a program of controlled weed harvest or herbicide application would be rapidly diluted by natural mixing, resulting in a relatively small increase in dissolved nitrogen or phosphorus, much less than the amount of nitrogen and phosphorus added to the enclosures in 1982. A moderate increase in phytoplankton might have the beneficial effect of inhibiting macrophyte growth through competition for light.

II. Macrophyte Growth

A. In 1981, the area occupied by big-leaf pondweed plants had increased by up to 100 percent in some parts of the reservoir since 1975. Comparisons of aerial photography obtained in 1981 and 1982 showed negligible changes in the extent of the plant canopy coverage between the two years. However, it appears that the increase in total coverage documented in 1981 in comparison to 1975 is not an isolated one-year condition, but is the result of continuous increases of pondweed over the past six years. If this trend continues at the rate estimated for the past six years, the zone now occupied by the pondweed will become completely covered with the plants within the next 10-20 years. This affects approximately 1250-1500 acres of the reservoir surface area (about 40-50%). This species will also probably extend its distribution into areas of the reservoir now relatively unaffected.

B. The extremely high macrophyte biomass attained in 1981 was not present in 1982, although the general distribution of the plants remained about the same. In shallow-water reference areas, a 60-70 percent reduction of plant standing crop occurred. A smaller reduction in standing crop of big-leaf pondweed (10-20 percent) occurred in 1982, compared to 1981, but the extent of the plant's distribution was not reduced. These results reflect the effects of heavy late snow cover and a difference in water level management in 1982, which seemed to reduce the total amount of aquatic weed growth in the reservoir. The general increase in macrophytes in the reservoir from 1975-1981 may be a result, in part, of hydrological conditions and reservoir management in the recent past, which have tended to stabilize water levels and appear to have increased water clarity.

C. Tissue analysis of macrophytic vegetation indicates the availability of nitrogen and phosphorus is not limiting rooted aquatic plant growth. Sediment analysis and enclosure experiments in 1981 indicate that sediment is the major nutrient source to the plants.

D. The water-milfoil present in Georgetown Lake was identified as Myriophyllum exalbescens, not Myriophyllum spicatum. M. spicatum is an introduced species which has caused problems in many parts of the country due to excessive growth and the displacement of other, more desirable and useful, plant species.

E. Measurements of dissolved oxygen production under the ice show that macrophytes do produce significant amounts of oxygen in April and May. However, algal oxygen production also increases during this period. The oxygen produced by macrophytes during winter is not sufficient to offset the oxygen consumed by winter decay of their biomass which accumulates during summer and fall. The major oxygen producing species under the ice is thought to be Potamogeton praelongus (big-leaf pondweed). Oxygen measurements made at shallow sampling stations indicate that algae growing in shallow water are probably responsible for a major input of oxygen to the lake during winter. Heavy snow cover during early spring can cause severe oxygen deficits and delay the recovery of dissolved oxygen concentrations.

F. Measurements of oxygen production and carbon uptake (plant growth) show that the aquatic macrophytes (weeds) accomplish most of the plant growth in the lake and contribute to the growth of zooplankton as well as aquatic insects and other benthic invertebrate animals, through the formation of detritus, which is the result of biochemical changes brought about by bacteria during the decay process.

III. Impact of Recreational Boating on Water Quality

Recreational boating was found to have negligible direct impacts on nutrient concentrations in areas 1.0 meters or more in depth. Although there can be no doubt that powerboats operating in shallow water cut off many aquatic macrophyte segments, which are capable of re-rooting in other areas, the complete distribution of macrophytic vegetation in suitable habitats throughout the reservoir negates this factor as being significant in the present or near future distribution of species. An exception to this situation would exist if specific areas were being managed for macrophyte control by harvesting, herbiciding, or other means. In that case, motor boating near or in the immediate area being managed could cause an increase in the rate of reestablishment of macrophytes on the cleared areas. The most likely affect of recreational boating at the present time is on shoreline erosion; however, natural processes in the winter of 1980 demonstrated a much greater affect on shoreline contours (due to ice heaving).

IV. Macrophyte Suppression/Control

A. Experimental harvesting of big-leaf pondweed in the Phillipsburg Bay area reduced standing crop the following year by 15-30 %. However, standing crops in other similar areas were also reduced 10-20 percent by natural causes; so this result is not clear evidence of suppression past the year of harvest.

B. Aquascreen effectively controlled macrophyte growth at the Grassy Point launch ramp; some growth did occur on top of the aquascreen application. However, the expense and difficulty of installation make this treatment unfeasible for large scale application. It is suitable for small scale use by individuals; however, it must be removed and reinstalled annually to be effective. SCUBA was found to be a suitable means of installation and removal, although the company gives directions for installation from the surface.

C. Herbicide was applied to big-leaf pondweed comunities in August, 1982. Approximately four acres were treated with Endothall and Diquat. Immediate results were not evaluated, due to the reduced growth of the plants this growing season. The aerial photography carried out during the monitoring program, combined with an on-site observation, will enable a satisfactory evaluation of the treatment.

D. Enclosure experiments in 1982 indicate that in-lake disposal of cut macrophytes is acceptable from a standpoint of nutrient loading. Addition of substantial amounts of nitrogen and phosphorus to enclosed phytoplankton communities resulted in increases in phytoplankton biomass to levels which were not above those obtained in other areas of the reservoir.

V. Sediment

Sediment cores indicated that while sediment accumulations are greatest in shallow areas due to the incomplete decay of macrophytes, sediment accumulations are not excessive over most of the reservoir. The average rate of sediment accumulation based on the results obtained from all cores was about 0.25 cm (0.10 inches)/year. The maximum rate calculated was 0.4 cm (0.16 inches)/year, the minimum was 0.13 cm (0.05 inches)/year. These rates are comparable to those obtained by other workers in similar lakes and reservoirs. Phosphorus profiles show an increase in concentration of phosphorus toward the sediment surface, based on dry weight. The higher concentration in the shallow sediment layers (3-6 inches) may be partly a function of, and at the same time responsible for the general trend of increasing macrophyte growth. Models of sediment phosphorus accumulation and sediment water interaction do not indicate that external sources are or have been responsible for the increase in phosphorus near the sediment surface. Phosphorus concentrations in surface sediments are in the same range as obtained for other shallow, eutrophic, lakes in the absence of intense cultural eutrophication. They are also similar to phosphorus concentrations in unfertilized Montana rangeland soils.

VI. Land Use

A. A survey of septic tanks around the shoreline indicated no significant chemical or bacteriological direct contamination of the reservoir by drainfield effluents. Five or six isolated septic tank plumes were identified, several of which have since been corrected. Bacteriological samples from all locations were within state DHES criteria.

B. There is approximately 700 acres of low density recreational development, most of which is residential. There was no detectable evidence of detrimental impact on water quality (as related to eutrophication) by this surface land use.

C. Some surface erosion due to road placement, and off-road vehicle use is apparent on the south and north shores of Jericho Bay. Off-road vehicle use is causing some loss of surface vegetation and associated surface erosion on both Forest Service and Anaconda Company holdings. Considerable dust is generated during the summer by vehicular use which may increse atmospheric nutrient loading.

D. Other recreational surface land use with potential for impact on water quality includes the Discovery Basin Ski Area, which now d plans an expansion, which will require removal of timber from an additional area for ski runs and lifts. The total acreage to be disturbed is not known, but probably less than 100 acres. The proposed disturbance is unlikely to have detrimental effects on water quality in Georgetown Lake due to its location, well away from streams or watercourses.

E. Timber has been harvested from a total of 1435 acres in the drainage basin (1308 Forest Service, 127 private). Additional harvest is planned for 352 acres, not including an undefined acreage for ski lifts at Discovery Basin (Forest Service managers estimate less than 100 acres). Infestation of the extensive lodgepole pine stands in the basin by mountain pine beetle is anticipated by Forest Service timber managers. This would require an expanded timber harvest in form of selective cutting of high risk sites to limit spread of the pest and control the danger of severe forest fires. The subsequent potential for increased erosion, siltation, and nutrient export can be controlled through revegetation of harvested sites, maintenance of buffer zones along streams and drainages, careful placement of access roads, and control of timber harvest practices.

F. Recent land use practices in the North Fork Flint Creek Drainage have not significantely impacted the chemical water quality of the stream on a permanent basis. Dissolved components (particularly nitrogen and phosphorus) and suspended sediment have remained near previously documented levels. Some year-to-year variability is observable and may be due to differences in the hydrologic cycle.

VII. Slag Evaluation

The smelting slag was not found to pose a hazard to human health through consumption of fish flesh. However, leaching experiments with lake water and water sampling indicated a potential for release of small amounts of heavy metals (Cu, Zn, Hg, Cd), which may have localized detrimental effects on aquatic life. A significant increase in cadmium concentration was found below the dam, which indicates that this element may be released from the sediment during certain conditions.

Analyses of plant tissues indicate that harvested plants may contain potentially toxic levels of Arsenic, especially if lake sediment is present with the plants in appreciable quantities. Should aquatic plants be harvested, they should not be used as garden fertilizer or as the sole source of feed for livestock. If sediment is removed by dredging, it should not be used as fill for domestic gardens or agricultural land. Potential sources of the arsenic and other elements found in the plant tissue include geological, the smelting slag, historical mining operations, and atmospheric transport. The contaminants were present in about the same concentrations in plant samples from widely separated areas of the reservoir, thus it does not appear that the substances are isolated to particular areas near roadways. It is possible that former operation of the smelter in

Anaconda resulted in atmospheric transport and subsequent deposition of the contaminants. The presence of the same contaminants has been documented in soils throughout the Deer Lodge Valley.

VIII. Public Attitudes on Land and Lake Use and Management: Questionnaire Results

Over 300 questionnaires were sent out to members of the Citizens Advisory Committee and Georgetown Lake Homeowners Association. A copy of the questionnaire is included as Appendix 1. Approximately 55% of the questionnaires were returned and analyzed.

Geographical Distribution of Respondents

The sampled population represents the local geographic area. Twenty-five percent classified themselves as permanent residents of the Georgetown Lake area; 50% were residents of Butte or Anaconda. Deer Lodge, other Montana, and out-of-state residents each accounted for 6%, while 3% were from Missoula.

Property Ownership:

Ninety-six percent of the respondents classified themselves as property owners in the Georgetown Lake area.

Land/Lake Use:

Respondents were requested to rank their recreational use of the lake and surrounding area in order of frequency or time spent. A use was considered a major use if ranked 1 or 2, a minor use if ranked 3-6. A use index was calculated by adding the frequencies of major plus minor use rankings, then dividing by the total number of rankings. Using this scheme, the following ranking of recreational importance was obtained:

1) fishing
2) boating
3) snowmobiling
4) other, including hiking, cross-country skiing, bird-watching, and other activities
5) waterfowl hunting
6) swimming
7) camping.

The low ranking of camping as an activity reflects the composition of the sampled population as primarily a resident population, most of whom are property owners. This questionnaire underestimates the importance of camping as a recreational use, as indicated by Forest Service data on campground use (see Land Use Section).

Recreational Values and Development

Fifty-four percent of the respondents indicated that some level of additional residential and public recreational development would not be objectionable from an esthetic and recreational standpoint. However, 81% favored restriction of commercial development, if necessary, to protect fishing quality, esthetic values, and water quality. Also, over 90% indicated that existing commercial services are adequate (this survey was taken prior to the destruction of the Denton's Point Restaurant and Lounge by fire).

Ninety-one percent said that housing density was not too high at present, however, 46% objected to additional residential or commercial development regardless of effects on water quality or fishing. Further, 36% favored restriction on development to protect fishing quality; 58% favored restrictions to protect esthetic values (scenery, solitude, etc.); and 67% favored restrictions to protect chemical and biological water quality.

Approximately 80% of the respondents indicated that present levels of recreational use and residential development did not interfere with their recreational activities in the Georgetown Lake area. Boating was most often given as a problem area, probably because of the high concentration of recreational boaters around the the area from Red Bridge ramp to the dam. On heavy use weekends, hazardous boating conditions can occur due to the intersecting path of boats coming out of the Butte Boat Club area and those coming from Red Bridge ramp or Phillipsburg Bay Campground.

Weed Growth and Recreation:

Overall, 82 percent of the respondents indicated that weed growths at the present density interfered with water-based recreation. Breaking this value down by activity group, 88 percent of fishermen, 70 percent of water skiers, and 75 percent of swimmers said that weeds interfered with recreational activity.

Use of Slag as Highway Sanding Material:

Relative to the use of Anaconda smelter slag to sand roads, eighty-eight percent said it was not esthetically offensive, eighty-eight percent were not in favor of using other material at increased cost unless it was shown that significant environmental contamination was occurring from the use of the slag, in which case eighty-seven percent favored the elimination of the use of slag as a sanding material.

Management and Funding

About half (forty-eight percent) were undecided on the formation of a special management district for weed control; thirty percent were opposed; twenty-one percent favored formation of a special management district for weed control in Georgetown Lake.

Fifty-one percent were opposed to any revenue raising fee structure for weed management; thirty percent favored some sort of fee structure incorporating daily use fees, annual use fees, and/or a special improvement district. The remainder were undecided.

Land Values and Landowner Benefits

Fifty-three percent said that landowners would benefit from a weed control program through increased property values, thirty-one percent did not think values would increase, and sixteen percent were undecided. When asked if they thought a weed management program would benefit landowners through improved recreational benefits, sixty-four percent said yes, eighteen percent said no, and eighteen percent were undecided.

MANAGEMENT RECOMMENDATIONS

I. Administration and Management

A. A permanent Georgetown Lake Management Committee should be formed as a special subcommittee of Deer Lodge/Granite County Planning Boards. The constitution of the committee should be as follows:

Chairman: Program Monitor
Members: Representative, Granite County Planning Board
Representative, Deer Lodge County Planning Board
Representative, Georgetown Lake Homeowners Assn.
Representative, Anaconda Sportsman's Association
Representative, U.S. Forest Service
Representative, Montana Department of Fish, Wildlife and Parks
Representative, Montana Power Company
Two members-at-large representing the general public.
Representative, Flint Creek Water Users
Representative, Anaconda Company

This group will replace the Clean Lakes Project Citizens' Steering Committee as advisory to the County Commissioners and respective planning boards, and should provide public input into management decisions affecting Georgetown Lake involving commitment of public funds, such as a harvesting program, and should also serve as a focus for public comment and concern.

B. It is recommended that contractual arrangements be established for a functional Program Coordinator to monitor and coordinate implementation of the management plan. Professional qualifications as an aquatic biologist, such as possessed by aquatic biologists of the MDFWP, DNR, or Water Quality Bureau, are essential. Satisfactory qualifications may also be possessed by private consultants or individuals working with private management companies, such as Montana Power Company. Supervision, agency liason, and administrative support could be privided by a county planning board or by the Deer Lodge/Granite County Sanitarian's Office. Responsibilities should include:

1) Coordinate activities during the drawdown management procedure in accordance with management guidelines in this volume
2) Prepare reports as required
3) Acquire annual data from management agencies as defined in "Continuing Data Requirements" section
4) Maintain files for future reference and management use.

Estimated Cost: $100/month

II. Proposed Chemical and Biological Monitoring Program

The following work elements should be carried out at 3 to 5 year intervals, as indicated by responses in reservoir water quality to drawdown or other management procedures. The monitoring activity should be implemented the first year after in-lake management alternatives are implemented, or as indicated by changes in land use or management objectives.

1. Aerial Photography. Thirty-five millimeter aerial photography is a cost-effective, timely means of evaluating changes in the critical plant communities in Georgetown. Baseline data is available from 1975, 1981, and 1982. The proposed photography should be obtained using the same type of equipment, format, and methodology as previously employed (Meyer, 1973). The photography should be taken between August 3-10, using a 35mm camera on a Meyer-type sidemount. Handheld photography is not permissible. Film should be ASA 200 Ektchrome. Photo scale is to be 1:20,000. Two flight lines shall be flown as described in Appendix 2, this volume. Slides depicting the previously defined study areas (Annual Report, Georgetown Clean Lakes Project, 1980-1981) will be interpreted and percent canopy coverge of Potamogeton species determined by using a dot grid or equivalent. A clear overlay should be generated compatible with existing overlays to graphically demonstrate changes in canopy coverage.

Cost Estimate (based on previous contract for similar work):

Aerial photography................	$600.00
Interpretation, graphics..........	300.00
Subtotal..........................	$900.00

2. Chemical Sampling. Water samples will be obtained between June 1-7 and August 1-7, 1983 at Station I as identified in the Annual Report, at depths of 1, 5, and 9 meters. Samples will be treated in the field as appropriate for analysis and preservation. Water temperature and Secchi disk depth (or extinction coefficient using a submarine photometer) should also be determined. Analyses should be performed for the following parameters, using EPA approved methods:

chlorophyll a
total phosphorus
dissolved inorganic phosphorus
total nitrogen
pH-alkalinity
conductivity

Additional samples should be collected in the months of January, April, and August at Station I and from the outflow below the power station for analyses of copper, cadmium, mercury, and zinc. The total number of samples would be approximately 6.

Cost Estimate for Chemical Sampling and Analyses:

6 man-days @ $100 per day	$600.00
Mileage: 500 @ 21 cents/mile	104.00
Chemical analyses (6 samples @ $75 each; 6 samples @ $50 each	750.00
Supplies	20.00
Subtotal	$1474.00

3. Plant Biomass Estimates. Plant biomass should be sampled once annually on or about August 15, in three areas, which are defined in Appendix 3. SCUBA will be utilized to remove all standing plant material within four, 0.5 m^2 quadrats in each area. The samples will be stored on ice and dry weights determined for each sample (drying at 85° C) to the nearest gram. Weights will be compared to samples from similar areas in previous years to obtain an indication of gross changes in plant density.

Cost Estimate:

SCUBA Crew	$250.00
Plant Analysis	50.00
Mileage: 250 @ 21 cents/mile	52.50
Subtotal	$352.50

4. Winter Dissolved Oxygen Concentrations. This element is currently being done by the Montana Depoartment of Fish, Wildlife, and Parks, and requires no additional funding. Dissolved oxygen concentrations should be monitored at two-week intervals at sampling stations as defined in Montana Department of Fish, Wildlife, and Parks Annual Reports on Georgetown Lake, 1975-1981, from February 15 through April 15 to determine if adequate oxygen is present for fish survival.

5. Monitoring Report. Data collected during the monitoring program should be compiled and evaluated with the existing data base by a qualified aquatic biologist, and used to reflect trends in reservoir conditions. The Project Monitor will be responsible for this aspect, utilizing expert assistance from the various state agencies. No additional funds are necessary for this work element.

III. In-Lake Management for Macrophyte Control

A. Objectives:

1. Reduction in distribution or canopy coverage of big-leaf pondweed (Potamogeton praelongus) by a maximum of 60 per cent, which represents the approximate distribution in 1970-1974. This level of reduction is considered compatible with protection of habitat necessary to maintain the high density of trout known to exist in Georgetown Lake.

2. Reduction in the standing crop of rooted aquatic plants in shallow waters (4-6 feet) below levels observed in 1981 (see Technical Report), while maintaining or increasing the present diversity of species composition.

3. Increase in late-spring/early summer phytoplankton standing crop and production above that observed in 1981 and maintain levels of phytoplankton comparable to those observed in summer, 1982. Algal chlorophyll concentrations should not exceed 12 ug/liter in June through July. Chlorophyll concentrations should not exceed 15 ug per liter in August through September. A decrease in phytoplankton standing crops below levels observed in the summer of 1982 is not desireable, in order to encourage competition for light between phytoplankton and aquatic weeds, and maintain or improve fish production.

4. A decrease in water clarity as compared to that observed in 1981 is desired to reduce light available to macrophytes in deeper waters. Secchi disc depths should be between 2 and 3 meters throughout the summer recreational season.

B. Management Alternatives

Overwinter drawdown
Mechanical harvesting
Chemical control (herbicide)
Dredging
Biological control (weed-eating fish; grass carp)
Sewage diversion
Bottom coverings (Aquascreen, black plastic, gravel)

1. Primary alternative: overwinter drawdown.

Rationale: Drawdown has been used in many cases to reduce, modify or otherwise manipulate macrophyte communities (Dunst, et al, 1974). The results have been variable, depending on the nature of the plant communities involved and extent and duration of the drawdown. Most success in controlling macrophytic vegetation has come after over-winter drawdowns of up to 4 meters (13 feet). A drawdown of this magnitude in Georgetown Lake is considered unfeasible, due to multiple use requirements, such as downstream irrigation water needs, recreational requirements, and creation of winter dissolved oxygen deficits which would probably prove lethal to a large percentage of the fish population. Drawdown has been shown to have the potential for controlling Myriophyllum species (Nichols, 1979), one of the major problem species in shallow water areas of Georgetown Lake, and to have slight or no effect through direct means on Elodea or P. richardsonii. In other cases, drawdown of various degrees has resulted in increased dissolved nutrient concentrations, sediment consolidation, increased algal growth, and increased fish production (Dunst, et al, 1974). Chemical and biological data from Georgetown Lake indicate that moderate drawdowns may increase the concentrations of dissolved nutrients and thereby increase phytoplankton growth. This result would tend to reduce the available light to macrophyte communities growing in deeper areas. The beneficial effects of drawdown in controlling undesirable macrophytic growth depend partly on the presence of snow cover, which will help reduce early spring macrophyte growth under the ice and leave more dissolved nutrients in the water for algal growth.

The depth/area relationships of Georgetown Lake are such that a major drawdown is unacceptable for previously stated reasons. The Technical Advisory Committee and Local Steering Committee discussed the options for drawdown procedures, and selected an experimental program in which the reservoir would be drawn down approximately 3.5-4.0 feet, feeling that this level may produce an acceptable condition of weed and algal growth, at the same time maintaining acceptable conditions for other water users. The surface area which would be affected by a drawdown of this magnitude is approximately 300 acres, which would be distributed as a narrow band 50-100 feet wide around the shoreline.

The reasons for selecting a drawdown procedure as the first management option included the following:

1. It does not create a condition which cannot be reversed.
2. It does not require the use of toxic chemicals or control agents.
3. It does not require a large capital outlay for equipment or supplies, and can be accomplished by the cooperation of existing management agencies who have the experience and professional qualifications to carry out the procedure under the proper controls and interpret the success or lack thereof of the procedure. Financial constraints in the community and state supporting agencies are such at the present time that options involving high technology solutions and large capital outlays for equipment or contract labor, such as might be required by an effective harvesting or herbicide program, were unacceptable.

Description of action: The reservoir is to be drawn down by stages to a minimum surface elevation of 6426.0 feet (Anaconda Gage). The following general guidelines have been reviewed and accepted by the cooperating agencies:

. Drawdown to between 6428.0-6428.5 feet (lake surface elevation on Anaconda Gauge) by October 30. The ranchers who use Flint Creek for irrigating downstream have indicated that their peak water needs occur in late July, August, and early September. The concensus obtained by discussion with the Georgetown Lake Homeowners, commercial operators, and other users indicates that a drawdown of 1-1 1/2 feet in late August and September is tolerable.

This will prevent excessive winter flows in Flint Creek, which might result in some flooding downstream due to ice formation.

. The reservoir level should be stabilized October-January and not drawn down below 6428.0 feet to minimize possibilities of severe oxygen deficit, which could cause a fish kill, and inadequate water availability for maintenance of downstream flows and refilling the reservoir the following year.

. Additional drawdown to 6428.0 could occur in February. Drawdown to a minimum surface elevation of 6426.0 should begin in early March, pending SCS forecasts of water yield from the drainage basin. These become available in early March and are revised in early April. The minimum lake level of 6426.0 feet should be obtained not later than April 10 and maintained for approximately 30 days before refilling begins. During the winter drawdown, dissolved oxygen concentrations should be monitored in February, March, and April to ensure that adequate oxygen concentrations for trout are maintained.

. A minimum concentration of 4-5 mg/L oxygen at a depth of one meter below the bottom of ice cover has been suggested by the Montana Department of Fish, Wildlife, and Parks as an acceptable condition for fish survival. Should oxygen concentrations drop to this level, drawdown should be stopped until recovery occurs. Previous data indicate that minimum dissolved oxygen concentrations under the ice usually occur in early to mid-March, and usually begin to increase in late March and early April due to increased oxygen production by algae and weeds.

. Calculations of flow requirements and average water yields are based on long-term data provided by USGS, SCS, and Anaconda Company. An analysis of the hydrologic budget by Montana Department of Natural Resources under two different discharge regimes indicates that this procedure could result in inadequate water to refill the reservoir four years out of ten if the plan were carried out under low precipitation conditions. It is critical that the final stage of the drawdown not be carried out in the absence of adequate water resources for minimum flow requirements.

. The Anaconda Company has agreed in principal to cooperate with this plan by diverting up to 3,000 acre feet of water from Silver Lake to Georgetown Lake via Hardtla Ditch, if required to bring the reservoir to acceptable pool 6429.0 by July 1, contingent on availability of runoff to Silver Lake.
This commitment is on a year-to-year basis and may not be extended past 1983.

. This procedure should be carried out over a period of several years (three-five) to determine its effectiveness. Should the monitoring program show that desirable results are not being obtained, or that undesirable conditions result, the drawdown program should be reevaluated and either modified or terminated.

Cooperating Agencies and Responsibilites:

- The Montana Power Company
    - a. operation of dam,
    - b. monitor snow survey reports from SCS,
    - c. monitor lake surface elevations.

- Montana Department of Fish, Wildlife, and Parks

a. monitor dissolved oxygen concentrations on a semi-weekly basis in February, March, and April. This is the continuation of a previous program.

- Anaconda Company
    - a. monitor lake surface elevations,
    - b. coordinate with Montana Power Company and Project Monitor to divert water from Silver Lake to Georgetown if required.

- Project Monitor
    - a. monitor activities and coordinate as necessary,
    - b. reports as needed.

Impacts:

- Will create lower winter oxygen concentrations by reducing volume:surface ratio.

- Will affect shoreline spawning areas of brook trout and kokanee salmon. Jim Vashro, Fisheries Biologist, Montana Department of Fish, Wildlife, and Parks and a member of the TAC, has reviewed this potential impact, and does not consider it to be detrimental to salmon or trout reproduction potential.

- Overwinter drawdown affects downstream users' water availability the following year.

- Will reduce shoreline damage by ice heaves.

- May cause increase in dissolved nutrient concentrations, increase in algal growth, reduction in water clarity. Drawdown may cause algal blooms if nutrient concentrations become sufficiently high. This condition is most likely to occur if water supply is short and the lake level is below normal the following summer.

- Will probably reduce shallow-water plant densities, but effectiveness will vary from year to year, depending on snowpack, weather, and runoff conditions.

Will probably not reduce rooted aquatic vegetation below levels in period 1970-1975

2. Alternative In-Lake Management Procedures.

If the drawdown procedure proves undesirable or ineffective, other in-lake management options are available.

A. Mechanical Harvesting.

This is the recommended alternative to water level regulation.

Discussion: Harvesting is a procedure to cut and, usually, remove rooted aquatic vegetation. Not usually referred to as a restoration technique, since it does not affect external sediment and nutrient income or alter conditions for regrowth, such as depth of sediment nutrients; it does provide immediate relief from nuisance rooted aquatic plants. If cut material is removed, harvesting can reduce affects of eutrophication because of the nitrogen and phosphorus tied up in plant tissues.

Advantages of harvesting include:

1. Immediate relief from nuisance plants.
2. Relatively free from deleterious side effects.
3. No toxic materials put in water.
4. Site and species specific - can plan activities for optimum results.
5. Can often result in reduction of plant growth for several years.

Disadvantages:

1. Cost - high capital outlay.
2. Labor costs.
3. Treatment must be repeated.
4. Possible algae blooms.

The process can be broken down into cutting, collection, processing, removal and disposal. Harvesting operations may employ only cutting or any combination of the parts. Harvested material is usually collected and removed from the lake basin. This creates additional work; the economic potential for sales of the material does not balance the added costs of transportation. Recent harvesting experiments carried out by the Corps of Engineers involved grinding the cut material in a barge-mounted grinder and disposal in the lake. No deleterious effects were noted, other than slight increases in dissolved nutrients. The harvested and ground plants did not propagate from processed cuttings, which were too small to regrow.

Considerations:

1. There are two kinds of plant growths creating problems in Georgetown Lake: (a) big-leaf pondweed in deep (12-20') water; (b) elodea, water-milfoil, and pondweeds in shallow (2-8') water. A

havester must be able to cut to a depth of 8-10' to be effective on the big-leaf pondweed, yet operate in 3-4' of water.

2. A large area has to be harvested. This requires high output, 1.5 to 3 acres per hour.

3. The reservoir is large, therefore the equipment has to be big enough to operate safely under most conditions.

4. The harvesting season is about 70 days. The maximum acreage that can be harvested is about 600-700 acres per year, one cut only.

5. In the absence of significant external nutrient loading from outside the lake, the reduced plankton algal growth, reduced nitrogen and phosphorus concentration in the water, and the potential for managing nutrients through regulating discharges, in-lake disposal is very feasible and may be desirable, to encourage algal growth that will help shade out more rooted plants. This is the recommended alternative for plant disposal. It is further suggested that cut material be collected and placed in submerged "compost piles" to prevent the excessive spread of vegetative fragments. These can be easily built from mesh wire and steel posts sunk into the bottom. The cut material is allowed to decompose under water, where it causes no odor problems, creates a gradual oxygen demand which does not cause a catastrophic dissolved oxygen deficit, and releases nutrients slowly, reducing the possibility of an undesirable algal bloom. This procedure has been used successfully in other areas (Russell Dunst, Wisconsin DNR, personal communication) with excellent success and avoids the necessity of transporting the harvested plant material to a disposal point.

6. It is not desirable to remove all or most of the rooted aquatic vegetation present in Georgetown Reservoir. Reduction of big leaf pondweed should not exceed 60 percent; shallow areas (4-10') should be treated on a spot access bases, i.e., harvesting should be limited to access areas and those used for shoreline fishing, until actual long-term affects can be evaluated.

7. Commercial equipment with the required operating characteristics is available from several commercial suppliers, including Aquamarine, Inc., and Limnos, Inc.

8. Costs for harvesting operations vary widely, from $20/acre on small systems to around $100-$125 per acre for large, multi-stage operations. Assuming a minimum of 500 acres per year over a five-year period, costs might be on the order ot $50,000 per year. There are options in establishing a harvesting program:

a. Do it yourself, non-profit corporation, buy equipment, provide own labor through volunteers. This could reduce costs over five-year period to about $60 per acre (2,500 acres X $60/acre = $150,000).

b. Contract with private corporation, etc. Current going rates about $100-$125 per acre. Advantages of no equipment maintenance, labor management, etc. ($125/acre X 2,500 acres = $375,000).

Recommendations:

This alternative should be seriously considered, in spite of high initial cost. It has the potential to yield multiple benefits beyond that of immediate weed removal (i.e better balance between algal and weed growth, better fish growth, long-term weed control equal to or better than other means, no disturbance of recreational use in the nature of a quarantine period of up to 14 days, which is usually required subsequent to the application of herbicides, and no impacts on downstream users. Further coordination with Department of Natural Resources' Water Quality Board should be considered about the possibility of using state funds for travel to view some successful harvesting operations should harvesting be reconsidered as the management option of choice.

B. Herbicides.

Discussion: This method of treatment is often used to spot treat high use areas. It's effects are usually temporary, as are those of harvesting.

Disadvantages:
1. Nonselectivity.
2. Inconsistent kills.
3. Dead material cannot be collected and moved.
4. Possible side effects from degradation products of the toxicant.
5. Temporary use restrictions on treated waters of up to two weeks.
6. Introduces toxic substances.
7. Algal blooms possible.

Advantages:
1. Ease of application.
2. Costs are in direct proportion to area treated; no large initial capital investment is required.
3. If good kill on a perennial is obtained, can have long-term benefits (big-leaf pondweed).

Costs: $30-$300/acre (pelletized forms $300/acre).

Recommendation: This might be considered as a secondary alternative to harvesting. Implementation of herbicide application on a large scale should be delayed until after monitoring in 1983 to determine effectiveness of Endothall and Diquat or controlling big-leaf pondweed. Use of herbicides is regulated by the Montana Department of Agriculture, Montana Department of Fish, Wildlife, and Parks, and Montana Department of Health and Environmental Sciences, and must be carried out under permit by a licensed applicator. The regulations concerning use of herbicides in aquatic environments are under revision and may be more restrictive in the future.

C. Other alternatives which had been mentioned as possibilities for lake management alternatives included the following:

1. Sewage diversion of shoreline septic systems. The results of the Septic Leachate Survey indicate that such action is unneccessary. Contributions of septic systems were found to be insignificant in terms of nutrient loading. Proper land use management in the future should be able to prevent any significant detrimental impacts on water quality from domestic sewage wastes.

2. Dredging. The average accumulation of aquatic sediments in Georgetown Lake is approximately 8-14 inches. A significant percentage of the lake's phosphorus and nitrogen load is present in this sediment, and dredging would probably reduce the total potential plant growth, reduce the possibility of algal blooms, and temporarily reduce aquatic weed densities, it probably would not bring about long term control of macrophytes, due to the clarity of the water, which would require increasing the average depth to about 22 feet from 16 feet to eliminate recolonization by the aquatic weeds. In addition, large scale dredging may bring about a major reduction in fish productivity, which, considering the emphasis placed on the fishery as a recreational resource, is not desired. The negative aspects, with particular reference to the expense involved in dredging, ranging from $0.35-2.00/cubic yard, resulted in the Local Steering Committee rejecting this alternative. Dredging is a viable alternative for the control of macrophytes in very limited areas, especially if accompanied by the placement of some sort of impenetrable substrate, such as black polyethylene film, covered with gravel. Such treatment can be effective in controlling plant growth for several years in areas to be used for swimming or boating access.

3. Biological control by herbivorous fish: Grass Carp. The use of grass carp is a controversial management option. Results obtained by the Corps of Engineers in an intensive evaluation of grass carp as a weed control agent have been variable, with good control being obtained in some cases, and relatively poor control in others, depending on the species and habitat involved. The use of grass carp, if considered further, will require the approval of the Montana Department of Fish, Wildlife, and Parks, and at best will be subject to careful experimentation prior to implementation. Disadvantages to this method include the inability to be selective in manipulating the macrophyte community, the need to restock the fish on a regular basis, the variability of response by the habitat and native species to the introduction of an exotic species, and the possibility of competition between grass carp and native species.

IV. Land/Lake Use and Resource Development

A. Objectives:

1. Maintain or improve existing water quality in the North Fork of Flint Creek and Georgetown Lake.

2. Maintain the existing quality of esthetic environment for a quality recreational experience at Georgetown Lake, including fishing, camping, boating, snowmobiling, hunting, and other outdoor pursuits.

3. Maintain adequate public access to the reservoir, including shoreline access.

4. Provide for resource and economic development opportunities consistent with the above objectives.

B. The EPA Clean Lakes Guidance Manual (Section 4) suggests a specific problem-oriented approach to analyzing basin land use impacts on water quality and developing a watershed management plan in coordination with a lake management plan. The specific steps toward developing the watershed management plan as they apply to Georgetown Lake are discussed below.

Situation Analysis: Land use and Water Quality

1. What is the specific problem to be corrected?
Excessive growth of rooted aquatic plants.

2. What factors or contaminants are principal contributors to the problem?
The major contributing factors to the existing condition are lake morphometry and sediment nutrient supplies, which result in excessive weed growth accompanied occassionally by low phytoplankton algae production. No evidence was found of excessive external nutrient loading from controllable natural or cultural sources.

3. What are the total mass loads of the selected contaminant entering the lake with a time frame characteristic of the problem?
Selected contaminants: Phosphorus and Nitrogen.
Time frame: annual
Mass loading: Calculation of a nutrient budget for 1981-1982 indicates a negative phosphorus budget. The rate of loss to gain is about 1.3/1.5 to 1. This is almost the same value as that obtained for data collected in 1973-1975, indicating little change in phosphorus loading balance over the past six years. The amount of phosphorus exported from the reservoir during the period from 16 June, 1981-31 May, 1982 is estimated at 1230 kilograms (2706 pounds); during the same period the amount of phosphorus entering the reservoir was estimated at 811 kilograms (1785 pounds). In addition, average phosphorus concentrations in the reservoir have decreased or remained about the same over the past six years, indicating a stable or decreasing loading relationship.

The nitrogen loading rate is estimated at approximately 1.0 $g/m^2/yr$. This is right at the limit of a "safe" loading rate, but is well below the lower limit for "dangerous" loading of 2.0 $g/m^2/yr$. Over 90 % of the annual nitrogen comes from natural sources which are not subject to alteration by management, such as groundwater, atmospheric, and normal runoff.

4. Sources of nutrient loads and relative amounts contributed by each?

The drainage basin is covered by natural vegetation to a great extent. About 1400 acres of timber have been removed, primarily on areas well removed from surface waters. There have been no apparent effects on water quality in the North Fork of Flint Creek; total non-filtrable solids (suspended sediment) loads have remained low (below 3-5 mg/liter, usually between 0.5 and 1.5 mg/l) and do not appear correlated with stream discharges (1980 U. S. F. S. data). Very little agricultural activity occurs in the basin above the reservoir; grazing pressure is very light and is not allowed on federal or Anaconda Company land adjacent to the shoreline. There are no point sources of sewage effluent, industrial waste water, or other contaminants. Cultural inputs appear to be limited to surface runoff from residential and commercial recreational development, and unpaved roads, which are subject to erosion during runoff and produce dust during summer. Based on results of the septic leachate survey carried out in the summer of 1981, inputs from septic systems located around the reservoir are insignificant (A total of 8 possible septic leachate plumes were located around the entire shoreline.)

5. What is the cause and effect relationship between load magnitude and problem intensity?

Considering the internal phosphorus and nitrogen supplies, natural nitrogen loading, and apparent availability of sediment nutrients to rooted aquatic plants, there appears to be little relationship between controllable external loading and problem intensity at this time. This is not to say that external loading could not be a problem in the future if improper land use practices were allowed to occur to a greater extent.

F. What degree of load reduction will provide an acceptable lake response?

It does not appear feasible to control the existing condition of excessive weed growth by reducing external nutrient supplies. An increase in residential, commercial or recreational development, especially in areas adjacent to the shoreline or the North Fork of Flint Creek, could cause problems in the future.

6. What load sources are controllable in principal; which are uncontrollable?

Uncontrollable sources include normal inputs from natural hydrologic sources (streams, precipitation, groundwater), direct runoff from natural vegetation, natural dry fallout such as pollen. Controllable existing or potential sources include erosion and siltation from subdivision construction and use, sewage and waste water contamination from new residential and commercial development, commercial fertilizers to promote lawn growth, dry fallout (dust) and silt from new roads for recreational and residential access, erosion from logging operations and logging access roads, erosion from surface mining and discharge of mine effluents, runoff from agricultural sources (grazing).

7. For the controllable sources, what management practices or control measures are available and practical in the basin being studied, given the site, institutional, and other constraints?

a)Dry fallout: dust control measures on perimeter and residential access roads, preferably blacktopping , which would help to prevent erosion during spring runoff and heavy storms. Although this may not seem like a significant source of eutrophication, the potential for future impact is difficult to assess and may be greater than expected. In addition, this control measure has the added benefit of improving the recreational environment, both from a standpoint of esthetics and air quality.

b) Contamination by sewage and waste water from residences and commercial recreational facilities: Adherence to existing state guide-lines for the construction and placement of septic systems, particularly in regard to slope, soil depth, permeability and ground water; the use of best available technology for septic waste disposal (for example, planned subdivisions with a lot size of less than 0.5 acres may require advanced waste water treatment systems, including tertiary treatment followed by drainfield application; passage of a shoreline protection act in both counties which provides for a "buffer zone" adjacent to the shoreline within septic systems cannot be installed, so that soils will not become saturated with phosphorus and natural vegetation can retard movement of inorganic nutrients. This zone should be a minimum of 300 feet in width.

c) Surface runoff and erosion from residential areas: Discourage shoreline residential and commercial development by passage of a shoreline protection act which provides a buffer zone around the shore line of Georgetown Lake and surface streams to prevent shoreline erosion and absorb nutrients and sediment in surface runoff from developments back from the shore. Prohibit the use of natural or commercial lawn fertilizers within 0.5 miles of the reservoir or running streams which drain into the reservoir. Require that any proposed subdivision with lake frontage provide for open park areas adjacent to the shoreline, and include plans for a combined launch/marina facility to reduce disturbance of the shoreline due to uncontrolled, dispersed construction of additional boat docks. All future subdivision applications and special use permit applications should :

i) incorporate the Planned Unit Development (P. U. D.) concept presented in the Montana Model Subdivision Regulations (MDCA, 1978), which clusters construction and maximizes the retention of natural qualities and land cover.

ii) include a plan for erosion control during construction, stockpiling of topsoil, and revegetation of disturbed areas within a specified time frame (12 months is suggested);

iii) minimize removal of natural vegetation and encourage maintenance of natural ground cover, particularly trees;

iv) plan access roads and drainage so that erosion potential is minimized and make provision for application of erosion control measures to areas adjacent to roadways, including culverts and diked sediment basins if necessary. Avoid the construction of unnecessary roads and construction of parking areas adjacent to erosion prone sites or near the shoreline.

v) utilize existing soil and land use suitability surveys to optimize land use and placement of developments. Discourage placement of roads and construction on unsuitable soil types or land use categories as defined in the Soil Conservation Service Special Soil Survey on the Georgetown Lake area, unless a site-specific survey indicates that unsuitable conditions do not occur on the selected site.

vi) include restrictive covenants on the use of commercial fertilizers to minimize nutrients in surface runoff.

d) Erosion from logging activity and access roads: managment agencies should leave buffer strips of vegetation with sufficient width along streams to control introduction of silt from erosion, employ erosion control methods at stream crossings, close and revegetate all inactive logging roads, and minimize the size of clear cuts to reduce sheet runoff. The wetland areas along the North Fork of Flint Creek are protected under the Montana Streambed Preseration Act and should be preserved, as they are probably acting as sediment and nutrient filters for the stream, and will help prevent the flow of nutrients and silt into Georgetown Lake from upstream erosion or development. The major timber manager in the basin is Deer Lodge National Forest. The Forest administration has been particularly responsive to maintenance of water quality in the drainage, as reflected in several policy and position documents. The present Forest Service monitoring program for the water quality of the North Fork of Flint Creek should be continued. In addition to Total Suspended Solids, ortho and total phosphorus, pH, ammonia, and fecal coliforms should be determined during high and low flow conditions.

e) Agricultural runoff: the present grazing levels should be maintained with one mile of the reservoir.

8. Other Factors: Use of Anaconda smelting slag to sand roads and highways.

Recommedations: Due to the finding of mercury in some of the water samples which had been exposed to slag, the presence of increased cadmium concentrations, and the mobility of zinc and copper out of the slag into lake water in laboratory experiments, it is recommended that the slag not be used to sand roads within one-quarter mile of Georgetown Lake or within 100 yards of bridges over running streams which drain into Georgetown Lake. It is also recommended that the monitoring program include collection of water samples from the reservoir and Flint Creek below the power station to verify enhanced levels of the metals mercury and cadmium. Samples should be collected in mid-winter, early spring, and late summer.

If a dredging project is undertaken, it is recommended that dredge spoils not be applied to agricultural areas or domestic gardens. If a harvesting project is implemented, plant material should not be used as mulch for domestic gardens or agricultural areas, for human consumption, or as feed for livestock.

C. Lake Use

1. Access

Results of the recreational use questionnaire indicated that present public access is adequate. However, much of the shoreline access now available to the public (approximately 50% of the total) is owned by Anaconda Minerals Company, which is in the process of selling many parcels in the area. Further subdivision and private real estate development on these shoreline areas would drastically reduce the total available access, which is now providing high quality recreational opportunities, including fishing, boating, picnicking, camping, and other outdoor recreational activities.

It is recommended that consideration be given by the county and state to acquisition of conservation easements or outright purchase of undeveloped shoreline to insure continued public access. Areas recommended for consideration are shown in Figure A, and total approximately three miles of shoreline.

2. Boating and Weed Control

Although the operation of outboard boats in weed-filled areas obviously causes the release of many small plant fragments, which are cut from the stems by propellers, the general distribution of all species in the reservoir leads to the conclusion that this factor is not significant in weed propagation or spread at this time. There are very few uncolonized areas available for the establishment of weed species already present. Natural processes are sufficient to accomplish the spread of weeds; therefore, no restrictions on boating activity or the size of boats used are being recommended. However, should intensive, large-scale, in-lake, management practices for weed control (such as mechanical harvesting) be implemented, further consideration should be given to the potential role of outboard boats in causing the spread of cut plant fragments.

LAND USE

Relationships of Land Use to Water Quality

The chemical and biological characteristics of lakes are related to the geochemical characteristics of the surrounding basin due to the downstream flow of dissolved materials derived from the weathering and dissolution of rocks and minerals which are exposed to water draining the area, as well as the decomposition and suspension of animal and vegetable components. Cultural activities with potential for impacting the trophic state and water quality of Georgetown Lake include logging, mining, agriculuture (grazing) and recreational use and development. The effects on water quality are usually due to the introduction of silt from increased surface erosion or the discharge of contaminating materials such as sewage, mining, or industrial wastes into surface or groundwater. There is also the possibility of direct effects on water quality from recreational use, such as shoreline erosion caused by boat wakes or excessive vehicle traffic.

The Clean Lakes Program is primarily addressed toward conditions which impact the usefulness of a lake by affecting the biological productivity (trophic state) through the process of cultural eutrophication, although it does not exclude other problems (Section 6.0, Clean Lakes Guidance Manual). This is due to fundamental differences in the nature of eutrophication, compared to such problems as bacterial contamination, introduction of toxic substances (such as heavy metals), or excessive siltation.

There is no industrial activity at present in the Georgetown Lake basin. The nearest industry of any significance to water quality was the Anaconda Company Reduction Works, 16 miles from the reservoir in the town of Anaconda. This facility used Georgetown Lake as a storage reservoir for industrial process water. There are no point source discharges, major mining activity, or significant agricultural activities in the basin upstream from Georgetown Lake. Some mining has occurred in the past and exploration is expected in the near future, as mineral deposits of economic significant are indicated in the area (U. S. Forest Service, Deer Lodge N. F. Planning Team, unpublished data; Ingman and Bahls, 1979). Timber harvest also has some potential for impacting water quality, primarily through increases in erosion and siltation to the North Fork of Flint Creek. The potential impacts associated with recreational use and developement are usually related to increased erosion during construction, increased surface runoff due to removal of natural vegetation and construction of roads, parking areas, and walkways, and increased nutrient export due to domestic sewage wastes and fertilizers.

Mathematical equations have been developed to relate parameters of water quality reflecting trophic state to characteristics of the drainage area and changes in land use. Because phosphorous and nitrogen are essential to plant growth, are commonly limiting nutrients in lakes, and are often affected by cultural land uses, most such equations deal directly with increases in phosphorous or nitrogen loading. Other factors, such as depth, suspended sediment, and sediment chemistry, also contribute to determine a lake's condition as to biological productivity. An increase in nuturient loading may or may not affect the biological productivity, or "trophic state", depending on the interplay of these and other factors. One of the major problems in developing and applying these equations is adequately determining the relationship between changes in biological conditions, water quality, nutrient "loading" from natural and cultural sources, and land use.

Some conditions do not lend themselves to direct determination, therefore equations or relationships relative to changes in water quality are not easily derived. Examples are estimation of nutrient inputs from "non-point" sources of nutrients, such as septic tank drainage or input from "dry fallout", such as dust. Another problem in the application of available models is that the problem condition, such as excessive growth of rooted aquatic vegetation, may not be directly related or immediately responsive to changes in nutrient loading because of internal sediment nutrient supplies which mask an overall change in nutrient input. Considering these problems, models may or may not provide guidelines for management relative to land use.

Land Cover and Use Classification in the Georgetown Lake Basin

The Forest Service has classified government owned lands in the Deer Lodge National Forest under their preliminary land type inventory (Ruppert, 1980). This system divides up areas into general use-capability areas, based on topography, soils, hydrology, and vegetation type. A total of 373 land types were identified in the Deer Lodge National Forest, many of which occur in the Georgetown Lake basin. Distinct land types may have many common characteristics which make them essentially the same for management purposes, such as vegetative cover, soil erodability, and soil permeability. The total number of vegetative types distinguished was 66, of which many are different phases of the same general type; for example Douglas fir timber type has a number of "phases", based on the kinds of vegetation with which Douglas fir occurs.

Soils in the Georgetown Lake drainage were classified by the Forest Service as being in the "Low" and "Moderate" erosion potential classes. This is reflected in the low total suspended solids (a measure of sediment and silt) measured in the North Fork of Flint Creek.

For purposes of the Clean Lakes Project, land cover/use was classified into seven classes. Classifications were made using USGS 7.5 minute quad maps, black and white aerial stereo photographs at a scale of 1:24000, and data from the Forest Service land use classification program. The classifications utilized are given in Table 1.

The Georgetown Lake basin was divided into seven sub-drainages and the percent of each land use/cover type in each subdrainage determined by planimetry. Table 2 summarizes the total percent of each land use/cover type in the entire basin. The percent of each land use/cover type in each subdrainage is shown in Table 3.

The most common land use/cover type in the basin is coniferous forest. For study purposes, rock outcroppings and talus slopes were included in this land cover type. Under the Forest Service preliminary inventory, 71 percent of the total area under Forest Service management is considered commercial forest with potentially harvesteable timber resources. Major timber types include lodgepole pine, Douglas fir, limber pine, subalpine fir, and mixed conifers. This comprises over 90 percent of the total forested area.

Table 1. Land Use and Cover Classifications used in the Georgetown Lake Clean Lakes Project.

Use/Cover Type	Symbol	Description
Coniferous Forest	(CF)	Timbered areas not adjacent to streams, or timbered areas not shown as wetland or riparian
Grassland/Meadow	(GL/M)	All grassland, including wet mountain meadows not in stream bottoms
Clearcut	(CC)	Self explanatory
Riparian/Wetland	(RP/WL)	Wet areas along stream courses around lakes which were identifiable by vegetation
Rural Residential	(RR)	Areas upon which homes have been constructed and an one acre radius around the structures.
Recreational	(REC)	Public campgrounds, picnic areas
Commercial	(CM)	Private commercial facilities

As of 1981, timber had been harvested from approximately 1400 acres, including 127 acres of private land. The method of operation has been primarily clear cutting in moderate sized blocks. The majority of clearcut areas occurred in the Stewart Mill Creek subdrainage (Area V). All are several miles from the reservoir, so have had little measureable impact on esthetics or water quality. Other small clearcuts have occurred in the Flint Creek subdrainage (Area VII), and several timber sales have been completed, with projected additional harvest in this subdrainage of 352 acres. This does not include the acreage which will be cleared for ski lifts and runs at the Discovery Basin Ski Area, which operates on a special permit from the Forest Service. This will bring the total acreage in this land cover type to approximately 1700 acres.

Table 2. Percent of land use/cover classes in the Georgetown Lake Basin.

Land use/cover type	% Total area	Acres
CF	76.19	25,830
GL/M	15.97	5,414
CC	5.60	1,900
RP/WL	1.22	414
RR	2.46	834
REC	0.41	139
CM	0.04	14

Riparian/wetland areas tabulated were associated with Georgetown Lake or the North Fork of Flint Creek. Acreages obtained were less than the Forest Service land inventory indicated because narrow riparian zones along the stream course were not included. Riparian-/wetland land cover type was primarily willow-sedge-grass scrub or sedge-grass wet meadows. There are several such wetland areas on the North Fork of Flint Creek (Fig. B) which should be considered critical habitats for water quality management, as they are probably acting as traps for sediment and nutrients from the upper drainage (van der Valk, et al, 1979; Boto and Patrick, 1979). The riparian zone bordering the North Fork of Flint Creek should also be considered critical habitat, as it stabilizes soils adjacent to the stream bed during high water and prevents erosion (Allen, 1979). The riparian land cover type also includes a narrow zone bordering the shoreline of Georgetown Lake within which vegetation is influenced by additional moisture seeping from the reservoir or shallow groundwater inflows. In general this riparian zone was considered to be approximately 50 feet wide, although in some areas (such as Stewart Mill Bay and the upper end of Phillipsberg and Rainbow Bays, it is considerably wider. The total area of this zone around the reservoir is approximately 78 acres (31.7 ha). It is important in intercepting nutrients and silt from direct surface runoff around the perimeter of the reservoir and protecting the shoreline from erosion. Wetlands in the Stewart Mill Bay area and along Highway 10A in the vicinity of Flint Creek are the only significant wetlands in terms of waterfowl production associated with the reservoir. These areas also contain some shallow marsh habitats which are heavily used by waterfowl in the fall.

The Rural Residential land use type includes subdivision tracts, individual tracts under private ownership, and tracts leased from the Anaconda Company and U. S. Forest Service. The total acreage tabulated in this type was 840 (341 ha). There are a total of ten platted subdivisions within a one mile radius of the reservoir. The average lot size, number of platted lots, and location by section are shown in Table 4. The total number of subdivision lots is 821. The overall average lot size is 0.77 acres; this includes some open areas in the old Eccleston's

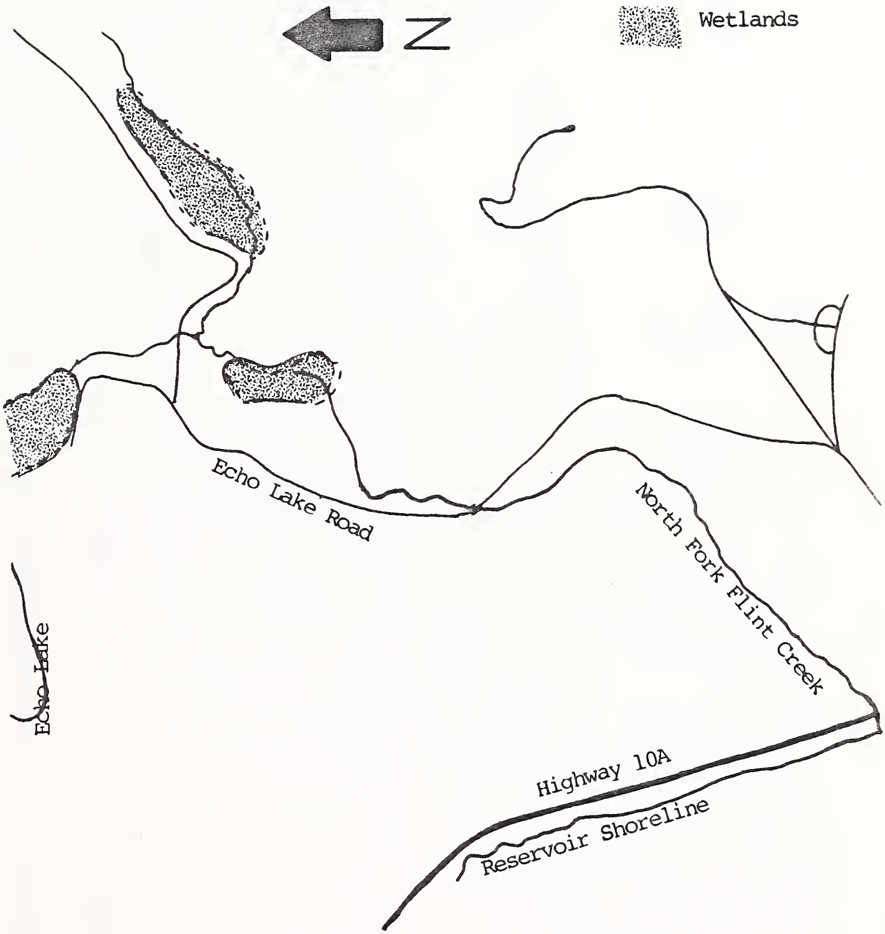


Figure B. Wetlands associated with North Fork of Flint Creek which should be preserved to maintain water quality.

Table 3. Relative areas of land use/cover types in sub-drainages of Georgetown Lake.

Area		% of Total Drainage	Land use/ cover Type	% of Subdrainage	% of Total
I	East Fork	6.36	CF	53	3.34
	2157 A		Gl/M	47	2.97
			RP/WL	<1 (0.4)	0.02
			REC	<1 (0.5)	0.03
II	Blodgett	10.73	CF	80	8.62
	3640 A		GL/M	14	1.50
			RR	6	0.50
			RP/WL	<1 (0.2)	<0.01
III	Edwards	1.46	CF	71	1.04
	495 A		GL/M	4	0.06
			RR	25	0.36
			RP/WL	<1 (0.2)	<0.01
IV	Denton's	2.20	CF	74	1.63
	746 A		GL/M	12	0.26
			RR	12	0.26
			RP/WL	<1 (0.4)	0.01
			CM	1	0.03
V	Stewart Mill	37.10	CF	86.2	31.98
	Creek		GL/M	4	1.48
	12584 A		CC	9.2	3.41
			RR	<1 (0.1)	0.04
			RP/WL	<1 (0.3)	0.11
			REC	<1 (0.2)	0.07
VI	Prospect/	4.99	CF	42	2.10
	Daly Gulch		GL/M	54	2.69
	1693 A		REC	<1 (0.2)	0.01
			RP/WL	3.3	0.16
			CM	<1 (0.2)	0.01
			RR	<1 (<.1)	0.01
VII	North Fork	30.14	CF	85	25.31
	Flint Creek		GL/M	11	3.31
	10,223 A		RP/WL	2.6	0.78
			RR	1.5	0.45
			REC	<1 (0.4)	0.12
			CC	1.0	0.30
			CM	<0.1	<0.01
VIII	North Shore	6.97	CF	32	2.23
	2364 A		GL/M	54	3.76
			RR	12	0.84
			REC	1.8	0.12
			RP/WL	2	0.15

Total Area 33,902 Acres

Subdivision which are not developed, but included in the subdivision boundary. The area occupied by subdivided lots is approximately 632

Table 4. Parameters of subdivisions in the Georgetown Lake area.

Subdivision	County	Range/Township/Section	Number lots	Ave. Lot size
Georgetown	Deer Lodge	5N/13W/17	176	0.08 Ac.
Tract	Deer Lodge	5N/13W/17	39	0.60
Sunset homesites	Deer Lodge	5N/13W/17	67	0.63
Mountain View	Deer Lodge	5N/13W/8	40	0.60
Denton's Tract	Granite	5N/14W/14	114	0.35
Georgetown Village	Granite	5N/14W/24	27	0.55
Edwards's Tract	Granite	5N/14W/24	117	0.30
			10	1-2
Lakeview	Granite	5N/14W/26	93	0.88
			1	28.1
			1	21.8
Shakopee heights	Granite	5N/14W/15	49	2.31
Eccleston's*	Granite	5N/14W/14	87	2.1

*Approximate lot size includes unplatted open areas. The actual lots are considerably smaller.

acres; this does not include access roads and open areas not platted for residential development, or isolated lots under lease or private ownership. The total area under subdivision, including access roads, is estimated at approximately 700 acres.

All recreational residential and commercial development to date utilizes on-site disposal of septic wastes. Waste disposal in all subdivisions approved since 1961 must meet minimum requirements set out under the revised Montana Water and Sewer Facilities Regulation (Regulation 136, adopted in Section 5, Chapter 95, Laws of 1961), as modified in 1963, 1970, and 1973, administered by the Montana Department of Health and Environmental Sciences. These state requirements are supplemented by local and county regulations, which are administered by the local sanitarian. Prior to 1973, subdivisions could be approved with sanitary restrictions on the individual parcels. Guidelines for the minimum lot size requirements for on-site disposal of sewage wastes required 10,000 square feet (0.23 acres) for a system if community water supply was used, and 20,000 square feet (0.46 acres) if both on-site sewage disposal and water supply were used. Subsequent to 1973, the lot size criteria was increased, requiring 20,000 square feet for on-site disposal with community water supply (or vice-versa), and 43,560 (1 acre) for on-site disposal and water supply.

State and Local Regulations Affecting Water Quality

The Montana Water Quality Act and Administrative Rules thereof (Appendix 4), administered by the Water Quality Bureau, Department of Health and Environmental Sciences, requires that a permit be obtained to construct, modify, or operate a disposal system, or construct or use any outlet for discharge of sewage, industrial, or other wastes into state waters. DHES may require monitoring of streams or lakes into which discharges empty, the installation of discharge flow controls, or other measures to insure that standards are met. Authorization is also required from DHES for short-term construction or hydraulic projects which may have short-term water quality impacts. Public notice must be given before permits can be issued.

Under Part III of the Montana Water Quality Act, a classification system was established for all public waters in the state of Montana. Georgetown Lake and all tributaries thereto have been classified A1, the highest classification for non-municipal water supply drainages. Standards have been adopted to establish maximum allowable changes in water quality parameters and a basis for controlling discharges of pollutants which might affect uses of lakes and streams. Limits are established for coliform bacteria, dissolved oxygen, hydrogen ion concentration (acidity), turbidity, temperature, suspended sediment and other solids, oils, color, and toxic or other deleterious substances (which may include nitrogen and phosphorous, where applicable) for the protection of human health, aquatic life, and beneficial water uses. For toxic and other deleterious substances, EPA national criteria are used, unless local conditions make more stringent values appropriate.

In December, 1982, new rules were adopted concerning non-degradation of high quality waters (Appendix 4b). Degradation is defined to exclude changes in surface water quality due to "non-point source pollutants from lands where all reasonable land, soil, and water management or conservation practices have been applied." This statement is specifically applicable to the agriculture and timber industries where resource utilization or management may cause some unavoidable effects on water quality.

Water analyses of the North Fork of Flint Creek, Stewart Mill Creek and ground water from shoreline springs do not indicate significant impacts on chemical or physical water quality from logging, mining, or recreational use at the present time. Although the potential for timber harvest is great in the Georgetown Lake drainage, existing Forest Service Management policy has placed emphasis on protecting recreational and water quality values. Forest Service hydrologists qualitatively assessed potential impacts of logging and burning, controlled or natural, on export of phosphorous and silt to the North Fork and Georgetown Lake. In view of the low erosion potentials, they concluded that increases in suspended sediment and phosphorous in the stream would be moderate and of short duration (one to two years) if proper management procedures were applied. These measures included leaving buffer strips along water courses, minimizing soil compaction by heavy equipment, and prompt revegetation of deforested areas. The presence of wetland areas on the North Fork of Flint Creek will help to reduce suspended sediment in the stream below them. Timber harvest from private land has been minimal, however, there is no guarantee that situation will not change. Logging activity per se on private property is regulated under the following state statutes:

75-2-211, 7-33-2205, 76-13-121, administered by Department of State Lands, concerning burning permits;

76-13-502, Department of State Lands, concerning operation of portable sawmills;

7-8-2608,2609, Department of State Lands, concerning timber harvest;

77-5-211,212,213, Department of State Lands, concerning timber harvest and slash disposal.

Potential impacts from mining are associated with road construction, transportation, surface disturbance during the mining process, mine waste-water discharge, and leaching from mine spoils. Hardrock mining operations are regulated by Statue 82-4-301, MCA, and Rule 26.4.101, ARM, administered by Department of State Lands. A reclamation and revegetation bond is required of mining companies unless a small miners exemption applies, in which case the operator must agree not to pollute streams. Hard rock mining permits may be denied if the operational plan does not comply with the Montana Clean Air Act, Montana Water Quality Act, or the Public Water Supply Act. Relative to mining operations, plans and specifications for tailing ponds, leach pads, and holding facilities must be submitted to the Water Quality Bureau for review and approval at least 180 days prior to commencing operations.

Construction in or disturbance of stream beds, banks, or wetland areas is regulated by the Streambed and Land Preservation Act (75-7-101, MCA) and the Rivers and Harbors Act (33 USC, 401 et seq.) Regulations are administered by the local Board of County Commissioners, Conservation District Supervisors, the Montana Department of Fish, Wildlife and Parks, and the Army Corps of Engineers. Notice must be given to the Department of Fish, Wildlife and Parks of all public or private construction or disturbance of streambeds, stream banks, and wetland areas for permit review. The purpose of this procedure is to minimize soil erosion and siltation to streams, after considering needs of agriculture and other beneficial uses of water.

Results of the Septic Leachate Survey and Dye Study indicate that septic tanks are not significantly impacting water quality at this time, nor are they responsible for the increased growth of aquatic weeds. Continued efforts to maintain properly functioning systems and upgrade below standard systems, coupled with proper planning of additional development to minimize construction near the shoreline, should provide continued protection for water quality in the future. Using Environmental Protection Agency guidelines developed during the National Eutrophication Survey, inputs of phosphorous from shoreline septic systems were estimated at less than 6 percent of the total estimated phosphorous input to the reservoir.

In the absence of extensive agricultural land use near the reservoir, the relatively low annual rainfall, and the natural condition of the vegetative cover, it is not anticipated that direct runoff would be a significantly manageable source of nitrogen or phosphorous input to the reservoir. Vegetative cover on most residential sites has remained in a relatively natural state. Many homeowners do not cultivate lawns and have kept most of their trees and native grasses, which minimizes increases in direct surface runoff. The maintenance of an intact shoreline "buffer zone" of natural vegetation is also minimizing inputs due to direct surface runoff from many residential or high use recreational areas. Exceptions occur where runoff is channeled onto roads and roadside drainage ditches. This is noticeable at Edwards' Subdivision, near the Anaconda campgrounds on the north side of Jericho Bay, and below Shakopee Heights. Although the magnitude of these inputs is not great, they probably constitute the largest volume of silt entering the reservoir through hydrologic means.

Subdivision and other residential development in Montana is controlled under the Montana Subdivision Law, which requires that developers submit preliminary designs to local and state agencies for review and approval. Since 1973, land could not be sold in parcels of less than 20 acres without prior lifting of sanitary restriction and or review by planning boards, which insures that public health will be protected. Subdivision approval require thorough review of local conditions pertinent to sewage disposal. That the subdivision review requirements are adequate to protect environmental quality is demonstrated by the recent Wanigan planned development, near Big Fork on Flathead Lake. During the review process, opportunities are provided for public input during public hearings held by the local planning board. The Montana Model Subdivision Regulations provide guidelines for future subdivision development under the Planned Unit Development concept, which clusters construction to minimize surface disturbance, and maximizes open space and retention of natural areas. The Planned Unit Development concept offers the greatest potential to realize the benefits of recreational and economic development while minimizing negative impacts on esthetics and the environment.

TECHNICAL
REPORT

DESCRIPTION OF THE STUDY AREA

Georgetown Lake, latitude 46° 10' 16" N, longitude 113 10'42" W, is formed by the impoundment of Flint Creek, in the Clark Fork River drainage (Fig. C). Highway 10A parallels the east shore for about 8 km. Early human activity in the area centered around mining and ranching. The site now occupied by the reservoir was used as pasture for cattle as early as 1872 (Lutey, et al, 1974). The first dam at the present site was built in 1885, and subsequent reconstruction, the last in 1937, raised the full pool water level to its present elevation of 6378 feet, msl (USGS, 1971).

Geology of the area is described in Alt and Hyndman (1972) and Ingman and Bahls (1979). The Flint Creek Range is composed mostly of complexly folded Precambrian metamorphic rocks and pre-Cenozoic sedimentary rocks with large granite intrusions. The general area is characterized as folded metamorphic formations, sedimentary deposits from an inland sea, subsequent uplift and erosion, leaving a fretted upland. The higher peaks in the area have elevations up to 10,000 feet (3200 m). The North Fork of Flint Creek has known gold and silver deposits, with mining activity occurring in the area as late as 1951. There are also deposits of gravel, clay, and limestone in the surrounding drainages.

Reservoir morphometric parameters are given in Table 5. These

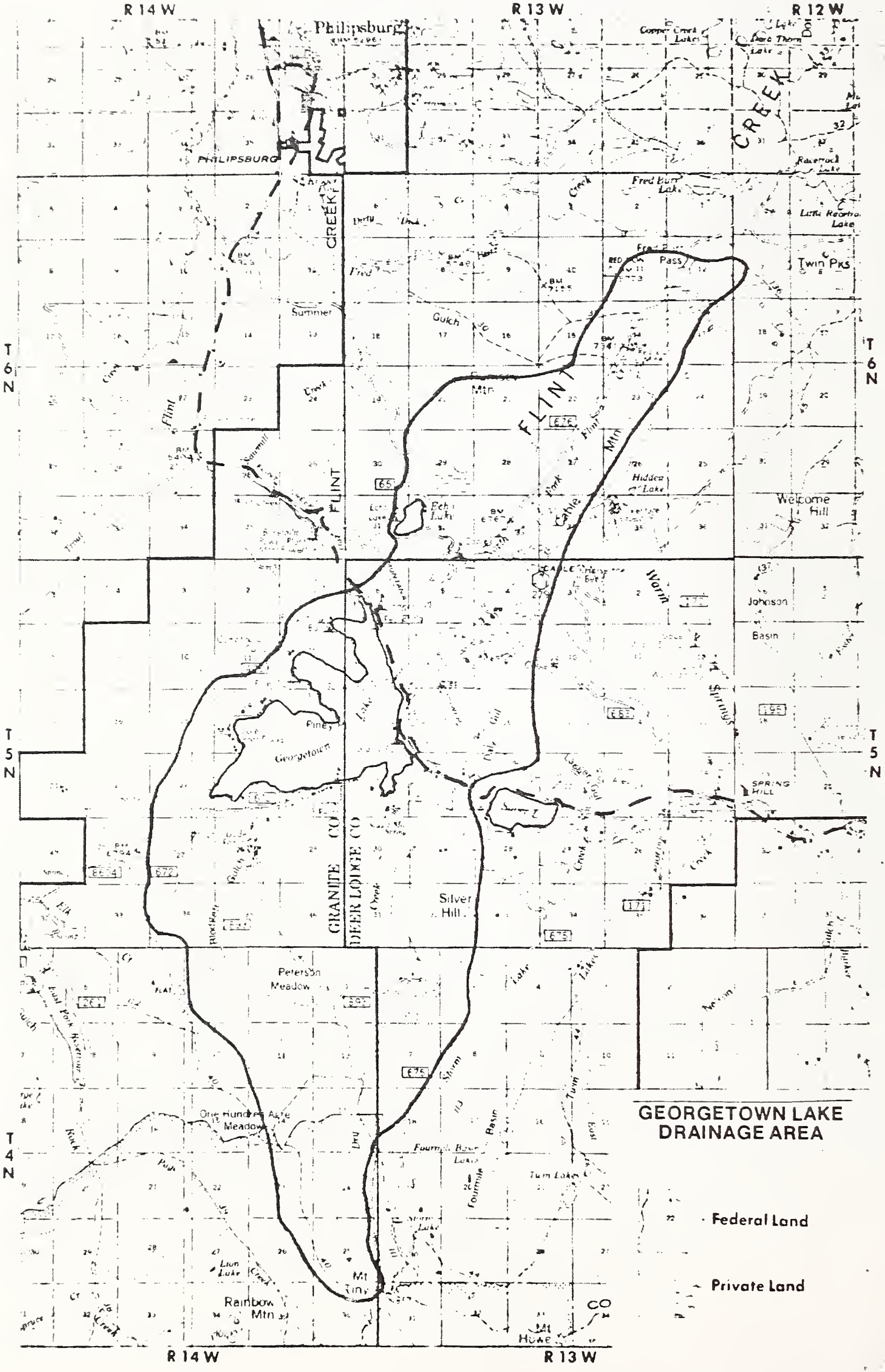


Figure C. Georgetown Lake Drainage Area.

were derived from a registered survey conducted in 1937 for the Anaconda Company by A. J. Davidson. Maximum surface area is given as 2,990 acres (1,210 hectares). Maximum mean depth is 16.0 feet (4.88 m). Shoreline length is approximately 17.4 miles (27.8 km).

Mean annual precipitation for the area is 18.75 inches (47.6 cm), measured at the Silver Lake precipitation gauge. Precipitation is substantially greater in the higher elevations [35-45 inches (89-114 cm)/year] surrounding the reservoir. May and June are the wettest months, averaging 32 percent of the annual total. Six of the last seven years (1975-1981) have had above-average precipitation, ranging from -27.5 to +79.4 percent of normal.

Average annual total evaporation was estimated at 35.4 inches (89.9 cm). Estimated monthly net evaporation values (net evaporation = total evaporation - precipitation) are shown in Table 6, based on pan evaporation measurements at several western Montana locations (NOAA, 1979) and evaporation estimates for small lakes and reservoirs derived by Meyer, (1942).

Hydrologic relationships in the Georgetown Lake area are complex, involving inputs from Silver Lake via the Hardtla ditch, North Fork of Flint Creek, Stewart Mill Creek , and a considerable groundwater flow. Outputs include the dam discharge via Flint Creek, pumping via the Anaconda Company aqueduct, which feeds back into Silver Lake, and possibly seepage. The mean annual discharge from Georgetown Lake is 29.6 cubic feet per second (cfs) (0.84 m^3/s). Silver Lake, in addition to its natural drainage, receives water

Table 5. Morphometric parameters of Georgetown Lake. Total volume 5.9158 x 10^7 m^3. Storage parameters in m^3 x 10^6. Area in hectares (ha). Surface elevation as feet on the Anaconda company gage. Mean depth in meters.

Surface Elev.	Surface Area	Change in Storage	Cumulative Storage	Cumulative Area	ean Depth
6429.5	1210.5				4.88
		1.835	1.835	13.48	
6429.0	1197.0				4.79
		1.815	3.650	26.84	
6428.5	1183.7				4.69
		1.798	6.065	40.16	
6428.0	1170.48				4.57
		1.774	7.222	53.36	
6427.5	1157.2				4.48
		1.754	8.975	66.52	
6427.0	1144.0				4.39
		1.734	10.710	79.64	
6426.5	1130.9				4.27
		1.714	12.423	92.63	
6426.0	1117.9				4.18
		1.694	14.118	105.55	
6425.5	1105.0				4.08
		1.675	15.793	131.17	
6425.0	1092.1				3.96
		1.655	17.448	143.48	
6424.5	1179.4				3.87
		1.633	19.081	159.68	
6424.0	1063.0				3.75
		1.608	20.714	159.68	
6423.5	1046.6				3.68
		1.584	22.273	175.75	
6423.0	1030.7				3.57

diverted from Storm Lake Creek during spring runoff. Under normal conditions, water from Silver Lake is diverted by the Anaconda Company through the Hardtla ditch, which is controlled by a headgate. Three thousand (3,000) acre-feet (3.7 x 10^6 m^3) or more of water may be diverted into Georgetown Lake, much of which may spill down Flint Creek due to insufficient storage capacity.

The reservoir drains an area of approximately 33,900 acres

Table 6. Net evaporation estimates for Georgetown Lake.

Month	Meyer (1942)		NOAA[1]		s. d.[2]	
	in.	cm	in.	cm	in.	cm
Jan	0.75	1.91	---	---	--	--
Feb	0.75	1.91	---	---	--	--
Mar	1.30	3.30	---	---	--	--
Apr	2.30	5.84	---	---	--	--
May	3.40	8.64	4.48	11.40	1.2	3.0
Jun	4.70	11.94	6.38	16.20	0.9	2.3
Jul	6.50	16.51	6.74	17.12	1.1	2.8
Aug	7.20	18.29	5.63	14.30	0.9	2.3
Sep	4.50	11.43	3.42	8.69	0.7	1.8
Oct	2.50	6.35	---	---	--	--
Nov	1.00	2.54	---	---	--	--
Dec	0.50	1.27	---	---	--	--

[1] Data from three western Montana meteorological survey sites (NOAA, 1977, 1978, 1979).

[2] Standard deviation of NOAA data

(13,725 hectares). The North Fork of Flint Creek is the major surface stream entering the reservoir, draining approximately 10,000 acres (4048 ha). Peak flows usually occur in May or June; these two months account for 55-80 percent of the total annual discharge. Extreme fluctuations in discharge are common. Total yield for May-June has varied from less than 2,500 acre-feet (3.09×10^6 m^3) to more than 15,000 acre-feet (18.52×10^6 m^3), a seven-fold variation. Minimal flows are usually obtained in October, averaging 5-8 cfs (0.14-0.22 m^3/s).

Stewart Mill Creek originates as a spring about 300 yards (meters) upstream from its entry into the reservoir, draining an area of approximately 10,400 acres (4,210 hectares). Discharge from Stewart Mill is much more stable annually and seasonally than the North Fork, reflecting its basic nature as groundwater. Data from

Knight, et al (1975) show that the annual discharge from Stewart Mill Creek varied by less than 10 percent from 1973-74 to 1975-75, while precipitation increased by 80 percent and annual discharge from the North Fork increased by 282 percent.

The remaining 4600 ha drains the area to the northwest and southwest of the reservoir. There is no surface discharge, but presumably groundwater flows to the reservoir.

METHODS

WATER CHEMISTRY

Water samples were collected using a portable, peristaltic, pump powered by a 12-volt battery. Discrete water strata were sampled by lowering tygon tubing to the desired depth and filling sample bottles from the hose outlet. Depth integrated samples were collected by lowering the hose intake to near the bottom and raising it through the water column at an even rate while pumping, then mixing the resulting sample thoroughly for subsampling.

A one-liter sample was filtered in the field using pre-washed glass-fiber filters for analysis of dissolved inorganic and organic components. A one-liter unfiltered sample was collected for determination of pH, alkalinity, conductivity, and suspended organic materials. Samples were stored in the dark on ice until analysis, which was initiated within 8 hours.

Dissolved ortho-phosphorous (as defined by EPA, 1974) was determined by the ascorbic acid-molybdate single reagent method (EPA,1974) on filtered, unpreserved samples. Total dissolved and total particulate phosphorous were determined on filtered and unfiltered samples, respectively, using acid-persulfate oxidation, followed by the single-reagent method.

Ammonia was determined by a manual phenol-hypochlorite method (Solorzano, 1969, EPA, 1974). NO3-nitrogen was determined by hydrazine reduction with a diazotization finish (EPA, 1974; Barnes, 1959). Nitrite was determined by direct diazotization of selected samples. Total organic nitrogen was determined by a microkjeldahl technique as described by Parsons and Strickland (1969), and EPA (1976), which utilizes a phenol-hypochlorite finish on digested, normalized samples.

The pH was determined in the laboratory using a pH meter with accuracy of 0.01 pH unit or better. Total alkalinity was determined by titration with 0.01 N acid to an endpoint of 4.50 pH units, which Knight (1980) consistently found to be the inflection point of the titration curve on Georgetown Lake water. Conductivity was determined with a YSI model 31 conductivity bridge, standardized with 0.01 M KCl (EPA, 1974). Samples were warmed to 25 C before analysis. Dissolved oxygen was determined in the field with a YSI model 54 meter and in the laboratory by Winkler titration.

Stream sampling stations were established in the same locations that were used in 1973-75 and designated NFF (North Fork, Flint Creek), SMC (Stewart Mill Creek) and FCO (Flint Creek, Reservoir Outflow). NFF was located about 100 meters above the bridge on Highway 10A; SMC was located just below the bridge on the road to Denton's Point, and FCO was located immediately below the Montana Power Company generating station. See Figure D.

Lake water samples were collected using a portable, peristaltic pump, powered by a 12-volt battery. Discrete water strata were sampled at two meter intervals at station I by lowering tygon tubing to the

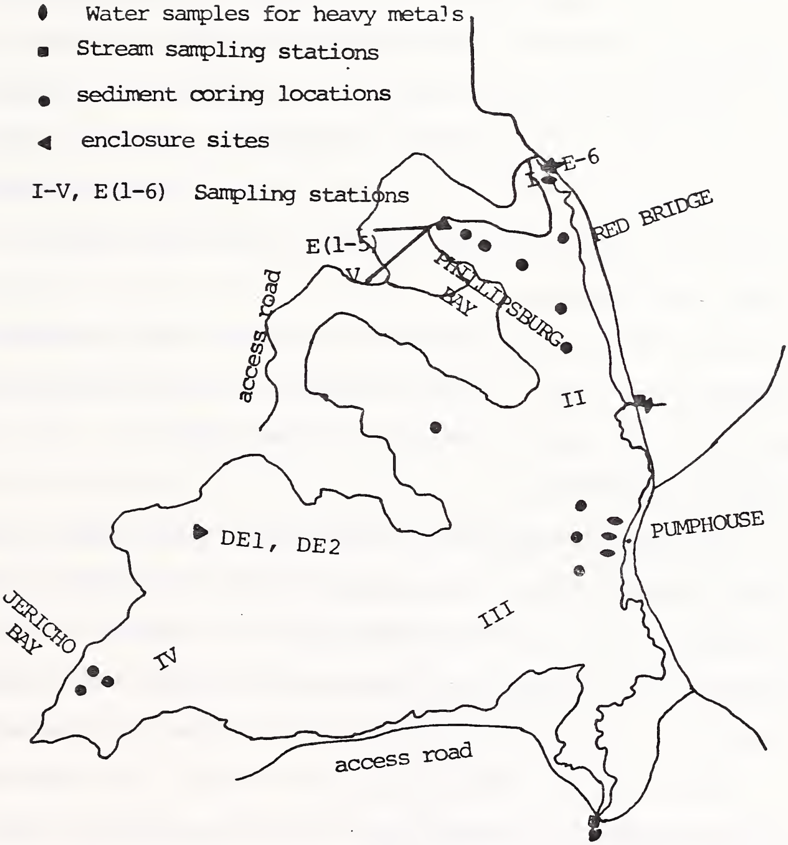


Figure D. Sampling stations, 1981-1982.

desired depth and filling sample bottles directly from the hose outlet. At stations I1-V , E-1 through E-5, C-1, and C-2, depth-integrated samples were collected by lowering the hose intake to near the bottom and raising it through the water column at an even rate while pumping, then mixing the resulting sample thoroughly for subsampling. All stream samples were collected as surface grabs directly into sample bottles or a 1000 ml graduated cylinder, using rubber gloves to prevent sample contamination.

Sites were sampled for water chemistry semi-weekly throughout the summer and early fall. During ice cover, sampling of selected sites was on a monthly basis, beginning in January, 1982.

LIGHT AND TEMPERATURE

Total daily solar radiation was measured using a Kip and Zonen Model CM-3 pyhrheliometer and an Esterline-Angus Model 80-M recorder, which were installed at the Montana Department of Fish, Wildlife, and Parks cabins on Highway 10A. Radiation measurements were converted to langleys per day as prescribed by the manufacturer's instructions.

Light intensity profiles within the reservoir were determined using a submarine photometer fitted with a Weston B56 photocell. Vertical extinction coefficients were calculated according to the definition and equation given by Hutchinson (1957). A mean vertical extinction coefficient was calculated for the water column by determining the percent transmission per meter from the surface to within one meter of the bottom (or the tops of macrophytes), then taking the natural logarithm of the arithmetic average of these values.

This method is analogous to the graphical method of Hutchinson (1957) and does not require interpretation of a nonlinear curve.

Water temperatures were measured with a standard laboratory thermometer calibrated to 0.1 degrees, or with a thermister in conjunction with a YSI Model 54 oxygen meter.

SEDIMENT CHEMISTRY

Sediment cores were collected in January, 1981, using a Hydro Products sediment corer. Cores were 3.5 cm in diameter and about 30 centimeters long. Intact cores with overlying water were stored in the plastic coring tube at -15 C until analysis. Cores were thawed, measured, and sectioned in 2 cm sections with a stainless steel knife. Sections were dried at 105 C, subsamples weighed and analysed for total phosphorous using persulfate digestion and acid-molybdate finish by Montana School of Mines Analytical Laboratory. Bulk density of sediment sections was determined by weighing an intact sample of a known volume, then drying as previously described, and reweighing to the nearest mg. Density is expressed as gm/cm^3.

HYDROLOGY

Influent streams were gaged in 1981 following the USGS method (USGS,1969), using Price AA and Pygmy pattern current meters. Staff gauges were installed in June 1981 on the North Fork of Flint Creek and Stewart Mill Creek, near the sampling stations NFF and SMC, respectively, and read several times weekly through September, weekly or semi-monthly after that through May, 1982. Discharge rating curves were constructed following USGS methodology and gauge data were used to calculate instantaneous and daily discharge. Discharge data for the North Fork of Flint Creek was also obtained from the Deer Lodge National Forest hydrologist at Butte, who maintains a recording gauge on that stream about 1 kilometer upstream from station NFF. Discharge data for Flint Creek below the dam (station FCO) was obtained from USGS and Montana Power Company, who maintain daily gauge records. Daily reservoir surface elevations, morphometric data, and other hydrologic data were obtained from the Anaconda Company offices in Anaconda, Montana.

Surveys for groundwater inputs were run using the Septic Leachate Detector concurrently with the septic leachate survey. In areas not covered by this method, a YSI conductivity meter was used. The conductivity cell was mounted on a submerged bracket attached to a small boat and slow shoreline cruises were made while monitoring the meter for changes in conductivity. Due to the biologically caused low conductivity of lake water during the summer of 1981, this method was found to be fairly effective in locating significant groundwater inputs. Other seasonal groundwater inputs were located during walking shoreline reconnaissance. Locations of these sources were noted on working, field maps and transferred to permanent maps in the office.

Water samples for chemical analysis were collected from submerged springs and shoreline seepage areas. Springs were sampled with the aid of SCUBA and the sampling pump described elsewhere. The springs were located using the Endeco Septic Leachate Detector (see Septic Leachate Survey), then sampled by placing the sampler intake immediately over the input zone. Samples were pumped slowly to minimize dilution and sediment disturbance.

AQUATIC PLANT COMMUNITIES

Limnocorrals were used to isolate aquatic communities for experimental manipulation and monitoring of chemical and biological changes.These enclosures were fabricated to specifications by Kepner Plastics, Inc, Torrance, California, from opaque, cloth-reinforced, poly-vinyl fabric. They varied in depth from two to approximately seven meters, and in diameter from approximately two to four meters. Triangular frames 3.9 meters on a side were attached to the outside of the larger enclosures with wood screws. The enclosures were anchored in place by steel rods driven through the skirt into the bottom, by weights attached to the external frame, and by a chain which was seamed into the bottom of the skirt, causing it to sink into the bottom mud and form a seal at the mud-water interface. Exchange of water at the surface was prevented by flotation collars, which provided about ten centimeters of freeboard.

Five of the enclosures were placed in water about 2.0 meters in depth at reservoir full pool. These enclosures were designated E-1 through E-5. They were installed between 24-27 June, 1981, after soaking in the lake for three weeks to remove leachable chemicals. They enclosed a mixed plant community which was composed of Potamogeton richardsonii (Richardson's pondweed), Myriophyllum exalbescens (water-milfoil), and Elodea canadensis (common waterweed), with an understory of Chara. Two control sampling stations were established in the immediate vicinity of these enclosures and designated C-1 and C-2. Another enclosure was placed in a deeper area, enclosing a phytoplankton community to a depth of about 6.5 meters. This enclosure was 2 meters in diameter, with a frame formed by plastic pipe circles. It was installed on 3 July 1982. These enclosures were monitored throughout the summer of 1981 and from January through May 1982.

In the summer, 1982 field season, enclosures E1-E4 were removed and modified to make 2 deeper enclosures 16 feet (4.89 m) deep. These were fitted with clear vinyl inserts in the walls to provide adequate light transmission to the interior and installed on 5 July, 1982, at the 15.5 ft (4.72 m) contour in a Potamogeton praelongus (big-leaf pondweed) community in Ecclestons Bay. This site was selected for uniformity of macrophyte cover and protection from wind and wave action.

One enclosure was used as a control to monitor enclosure effects on plankton and macrophyte standing crop, nutrient chemistry, and community metabolism. The other was subjected to periodic nutrient additions of nitrogen and phosphorous. Chemical dynamics, phytoplankton chlorophyll, light penetration, temperature, and benthic and planktonic metabolism were monitored throughout the summer. Planktonic communities were isolated for measurements by the use of smaller clear vinyl enclosures (4 dm in diameter x 4.5 m deep). These small enclosures were not left in place all season, but were filled with water from the larger enclosures and monitored over a 24-48 hour period, then removed until the next sampling period.

REMOTE SENSING AND MAPPING OF SUBMERGED MACROPHYTE COMMUNITIES

The distribution and composition of aquatic plant communities was investigated using color infra-red aerial photography. Aerial photography of aquatic macrophyte communities was obtained in early August, 1975, by Dr. R. L. Eng, Biology Department, Montana State University, and in early August, 1981-1982, by Jeff Ryan, ECON, Inc., Helena, Montana. A 35mm camera and ASA 200 Ektachrome color slide film were used. The camera was mounted on a Meyer side-mount attached to a small, fixed wing aircraft. Line transects covering all areas of the lake were selected and photographed at a film scale of 1:20 000. Details of this method are found in Meyer (1973).

Interpretation of the photography was done by the author. Slides were projected onto transparent plastic film and community outlines delineated with an ink pen. Recognition of distinct community types depended on texture, color, and pattern of the photographic imagery, within the context of ground investigations to determine reference areas. Locations were found with overlapping coverage from all three years of imagery and composite maps showing changes in coverage and community distribution were generated photographically. Areas of selected community types were determined using a dot grid. Changes in extent of communities between years were determined by subtraction of dot grid totals.

AQUATIC PLANT COMMUNITIES: STANDING CROPS

Standing crops of selected macrophyte communities were sampled with the aid of SCUBA. Quadrat frames (0.5 m^2) were fitted with a floating skirt approximately 1 m in depth to facilitate location in deep plant beds. Frames were placed randomly in selected plant communities. Plants enclosed within the frame were collected by hand, stored in plastic bags on ice in the field, and deep-frozen in the laboratory until analysis. Later, samples were washed, and dried at 90 C for a minimum of 48 hours. Samples were weighed to the nearest 0.1 g on an analytical balance.

Standing crops of phytoplankton were estimated by chlorophyll a extraction. Water samples were filtered in the field using Gelman type A glass fiber filters or equivalent and filters were immediately placed in 90% spectral grade acetone in accordance with procedures recommended by EPA (1975). Extracts were stored in a freezer until spectral analysis. Pigment concentrations in extracts were determined in extracts with a Bausch and Lomb Spectronic 88 spectrophotometer. This instrument was standardized with EPA quality control chlorophyll samples and a Beckman DU spectrophotometer located at Montana State University with the aid of Dr. James Pickett, MSU Biology Department. Pigment concentrations were calculated using the trichromatic equations described in Parsons and Strickland (1972) with correction for phaeophytin.

Samples for phytoplankton community composition were collected concurrently with chlorophyll samples. Composite samples from all stations were collected by taking depth-integrated vertical samples, then taking a 125 ml aliquot, which was preserved in the field for enumeration and identification of taxa in the laboratory. Phytoplankton samples were later resuspended, an appropriate volume concentrated and organisms identified and enumerated according to methods described in Vollenweider (1969). Individuals were identified to the lowest practical taxon, using keys presented in Prescott (1962), Smith (1950), Patrick and Reimer (1966), and Hustedt (1930). Phytoplankton organisms were measured to determine cell volume parameters, which were calculated by assuming appropriate geometrical formulae (Vollenweider, 1969). Standing crops were expressed as cell volume $(mm^3)/m^3$ and ug chlorophyll a/liter.

COMMUNITY METABOLISM

Community metabolism was measured in enclosed and unenclosed communities by the diurnal pH-CO_2/O^2 method as described by Odum and Hoskin (1958), Park, et al (1958), and Beyers, et al (1963). Sampling sites selected for diurnal measurements included Station I, the five littoral enclosures (E1-E5), and two littoral control sites (C1 and C2). A Beckman Model GS pH meter was used, enclosed in a plastic bag, as recommended by Park et al (1958). Oxygen measurements were made with a YSI oxygen meter. Electrodes were inserted in a flow-through cell, through which a continuous sample stream was pumped from the water strata being sampled by a battery-operated peristaltic pump. The vertical interval between samples varied depending on the depth at the site. The minimum interval was 0.25 m, the maximum was 1.0 m. The pH meter was calibrated for each set of measurements using buffers within the measured pH range which were suspended in lake water to maintain them at the ambient sample temperature. The dissolved oxygen meter was calibrated according to the manufacturer's instructions for each set of measurements. Subsequent to September 3, 1981, pH measurements were made in the field laboratory using an Orion 801 meter. The theoretical precision of the pH meters used is 0.003 pH unit; measured values were recorded to 0.01 pH unit.

All diurnal measurements were carried out over at least 24 hours. During the daylight measurements were made at approximately 4 hour intervals. A run was made at sunrise and sunset, and one set of samples were collected about half-way through the night. For the calculation of carbon uptake versus pH change, empirical pH/CO2 curves were constructed for lake water according to the CO_2 titration technique described by Beyers, et al (1963). Community respiration and photosyntheses were calculated as mg C or O_2/m^2/unit time. Carbon and oxygen changes at each depth were integrated graphically for each site to arrive at area-based values. Volume based values were derived by dividing the area-based values by the site depth.

HARVESTING

Harvesting of selected macrophyte communities was carried out in August, 1981 to determine the potential long-term effects on macrophyte growth. A mechanical harvester was used which cut a path approximately 8 feet (2.6 meters) wide and 4 feet (1.3 meters) deep. A total area of approximately one hectare (2.5 acres) was cut, in the Potamogeton praelongus community type located near Station V in Philipsburg Bay. Samples of standing crops before and after mechanical harvesting were collected by hand with the aid of SCUBA. Methods of sampling were as previously discussed.

SEPTIC LEACHATE SURVEY

A study of septic tank effluents using fluorescent dye was carried out July 11-19, 1981. Approximataely 15 milliliters of Rhodamine WT dye was introduced by hand into 200 septic systems near the shoreline of Georgetown Lake on July 11, 1981. Dye tracing began on July 14, using a Turner Model 111 fluorimeter equipped with a flow-through cell and filters as recommended by the Turner Manual of Operation. Stable electrical power was provided by a 110 volt gasoline generator equipped with an inline voltage stabilizer. A small, 12-volt, submersible, bilge pump was mounted on a section of rigid plastic pipe and connected to the fluorimeter cell with tygon tubing.

Prior to each survey, the fluorimeter was calibrated to full scale deflection with a solution of lake water containing about 0.1 ppm dye. The apparatus was placed in a small boat manned by two people, one to operate the pump, the other to monitor the fluorimeter and run the boat. Surveys were made by running the boat along the shoreline at slow speed while pumping a steady sample stream from just below the surface through the fluorimeter cell. Deflections were recorded on portable recorder attached to the fluorimeter.

In addition to the dye survey, a shoreline septic leachate survey was performed July 6-10, 1981, using an Endeco Model 2100 "Septic Leachate Detector". This instrument is essentially a two-channel recorder which simultaneously amplifies and records inputs from a sensitive conductivity bridge and a fluorimeter which responds to fluorescence from dissolved organic decay products. The application of the apparatus to the detection of septic leachate contamination in surface waters depends on the presence of inorganic ions (Na, K, Cl) and dissolved organic decay compounds at higher concentrations in leachates from septic tank drainfields than in the surrounding water. A small submersible pump introduces a continuous flow sample to the detection cell. A simultaneous increase in conductivity indicates the the contamination of lake water by septic leachates. A further description of the operating characteristics is found in Appendix 5. The area of contamination is called a "plume".

Field procedures are similar to those described for the dye survey. Field work and data interpretation was directed by Dr. James Yanko (Swanson Environmental Services) assisted by project personnel and representatives from the Montana Water Quality Bureau. Surface grab samples for chemical and bacteriological analyses were collected from all identified plume areas. Chemical analyses were performed by personnel of the Georgetown Clean Lakes Project. Bacteriological analyses for fecal coliforms and fecal streptococci were done by the Montana School of Mines Bacteriological Laboratory in Butte.

EVALUATION OF SMELTING SLAG

The potential or existence of environmental contamination and hazard to human health was investigated by five approaches.

1. Water samples were collected from the reservoir, groundwater, and surface streams in the area of sanding operations and analysed for toxic metals known to be in the slag.

2. Snowmelt which was exposed to the slag along the roadside was analysed.

3. A slag-sediment leaching experiment was run using water from Georgetown Lake.

4. Fish were collected from the reservoir and tissues analysed for toxic metals.

5. Aquatic plants were collected from the reservoir and analysed for toxic metals.

Surface and Ground Water Samples

Water samples were collected 13 April, 1982 for toxic metals analysis. Samples of lake water were collected from three locations along the shoreline adjacent to Highway 10A in an area about 15-30 feet off-shore and 100 feet south of the Anaconda Company pump station, using a peristaltic pump and tygon tubing, into acid-washed plastic bottles. The samples were pumped from the water strata immediately above the sediment. This represents the water layer in which concentrations of metals would probably be highest, due to release from the sediment surface. Ground-water samples were collected from springs which were flowing out of the shoreline gravels just above the water-line. Grab samples were collected from North Fork Flint Creek, Stewart Mill Creek, and Flint Creek below the power station. Sampling locations are shown in Fig. D. Dissolved oxygen and temperature were measured with a YSI Model 54 meter. Water samples were refrigerated until transported to the Analytical Division, Montana Bureau of Mines and Geology, Montana College of Mineral Science and Technology, Butte, Montana for analysis.

On 1 May, 1982, a sample of snowmelt which was running through roadside accumulations of sanding slag and draining into the reservoir was collected. The sample was filtered through a pre-washed glass fiber filter using an acid-washed glass filter apparatus to remove fine particulates.

Leachates From Slag and Sediment into Lake water

Samples of sediment were collected from Georgetown Lake near the Anaconda Company pumphouse on Highway 10A (Fig. D) about 30 feet offshore on 13 April, 1982, using an Ekman dredge. Sediment was placed in seal-lock plastic bags and kept cold until experimental treatment was started. Water samples were collected from just under the ice to avoid influences of sediment exchange and stored in acid washed glass bottles at 4^{o} C. Slag was collected at the Anaconda Company Reduction Works, fractionated according to size classes by seiving, and stored in Whirl-pak plastic bags until treatment.

The leaching experiments were carried out in 250 ml erlenmeyer flasks that had been acid-washed and thoroughly rinsed with distilled, double de-ionized water. Lake water was purged of oxygen by flushing with bottled nitrogen gas, then the pH adjusted to about 5.2-5.6 by bubbling CO_2 through the sample. This treatment approaches biologically-obtainable conditions near the sediment-water interface in Georgetown Lake. Reconstituted slag subsamples were composed of 5% fine fraction (<125 um), 20% medium fraction (125-150 um), and 75% coarse fraction (150-500 um), which approximated the average composition of the slag sample obtained from the source which is used for sanding highways. Loading was 1 g, 3 g, and 5 g slag per 150 mls lake water.

Sediment samples were mixed thoroughly, weighed out in the experimental flasks, and covered with 150 mls lake water. Sediment loading rates were 0.547 g, 1.949 g, and 4.264 g dry weight per 150 mls. Control flasks were filled with 150 mls of lake water. The air space in the flasks was purged with nitrogen, then immediately capped to prevent oxygen exchange, and incubated in the dark for 20 days at 3 C. Flasks were agitated daily by manually swirling the samples for about 60 seconds. Final pH was determined with an Orion Model 801 meter; final dissolved oxygen was determined with a YSI Model 54 meter. Water samples were double decanted into sealed plastic sample bottles and immediately sent to the lab for analysis. Metals analysed included mercury, cadmium, zinc, chromium, lead, and copper.

Fish Tissue Analysis

To further investigate the potential human health hazard from slag leachates in Georgetown Lake, trout muscle tissue was analysed for mercury, arsenic, lead, and cadmium. These metals were selected based on discussions with Dr. Glen Phillips, MDFWP pollution biologist and technical liason . Three specimens of brook (Salvelinus fontinalis) and rainbow (Salmo gairdneri) trout, respectively, were collected June 23, 1982, with the aid of MDFWP fisheries biologist James Vashro, from the area adjacent to Highway 10A, which would contain fish most likely contaminated by any slag leachates. Fish were measured in the field, then placed in plastic bags and kept cold until tissue samples could be taken. Muscle tissue samples were cut from the side just forward of the dorsal fin, rinsed in distilled water, and sealed in whirl-pak plastic bags. Samples were frozen until taken to the Analytical Division, Montana Bureau of Mines and Geology, Montana School of Mineral Science, Butte, Montana.

Analysis of Plants for Toxic Substances

Plant samples were collected from the shoreline adjacent to Highway 10A near the Anaconda pumphouse, from Phillipsburg Bay, and Stewart Mill Bay. Samples were rinsed in lake water, placed in plastic bags, and frozen until analysis, which was performed by the Analytical Laboratory, Montana State University Agricultural Research Station. Six samples, representing two different plant communities, were analysed for arsenic, selenium, cadmium, copper, zinc, and mercury.

RESULTS AND DISCUSSION

RESERVOIR HYDROLOGY, MORPHOMETRY, AND OPERATION

The hydrologic budget for 1981-1982 is shown in Table 7. The North Fork accounted for 32 percent of the total basin water yield in 1981-82. Total discharge from Stewart Mill Creek in 1981-82 contributed 22 percent of the total annual water yield for the basin. Annual discharge from Stewart Mill in 1981-82 was approximately 11 percent greater than discharge in 1974-75 (Knight, et al, 1975), while the North Fork decreased by 8 percent. Average annual discharge from Stewart Mill, calculated from data for 1973-75 and 1981-82, is 6,529 acre feet (8.059×10^6 m^3), with a standard deviation of 837 acre feet and coefficient of variation of 0.128.

Table 7. Hydrologic budget for 17 June, 1981-31 May, 1982.

Source	Inputs $m^3 \times 10^6$	Outputs $m^3 \times 10^6$	Percent Total
North Fork	12.2926		32
Stewart Mill	8.732		22
Hardtla Ck	1.194		3
Groundwater	16.686		43
Flint Ck		40.8329	92
Net Evaporation		3.6517	8
Storage	-5.5893		
Total	38.891	38.891	100

Approximately 4530 hectares are not drained by any surface stream, thus the only discharge from this area is groundwater. Evidence also points to considerable groundwater flow from Silver Lake to Georgetown when Silver is approaching capacity (Personal Communication, Phil Farnes, SCS, Bozeman, Mt). Approximate locations of groundwater inputs are shown in Figure E, which identifies three probable areas of most importance, in terms of volume. Other areas of submerged groundwater input were located in upper Stewart Mill Bay and Jericho Bay. Some subsurface discharge also occurs along other shoreline areas during late spring and early summer. The presence of wetlands type vegetation on the east shore and adjacent area of Stewart Mill Bay and south shore of Jericho Bay indicate probable groundwater discharge.

Monthly average groundwater flow in 1981-82 varied from a high of 53 cfs in June to an average of 16 cfs during January-May, 1982. Groundwater contributed 43 percent of the total basin water yield for 1981-82, with a total yield of 1.668 x 10^7 m^3. Data recalculated from Knight, et al (1975) show that groundwater flow accounted for 50 and 40 percent of the total basin yield in 1973-74 and 74-75, respectively. For the three year period, the average groundwater discharge is 13,197 acre-feet (1.629 x 10^7 m^3), with a standard deviation of 2.19 x 10^6 m^3 and coefficient of variation, 0.134.

The correlation between percent groundwater flow and total yield is negative, indicating that surface flows account for most of the variation in basin yields. Over the three year period for which data are readily available, groundwater flows (which in this sense include

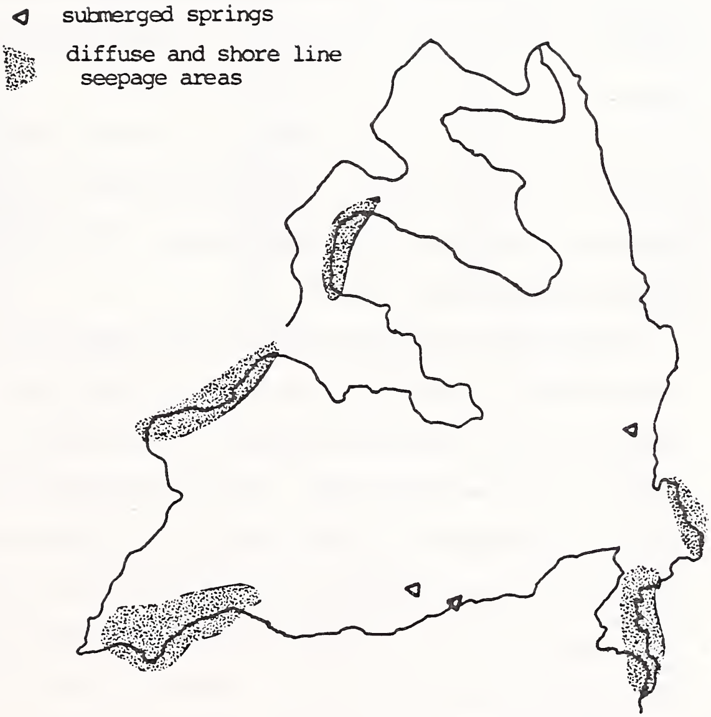


Figure E. Approximate locations of groundwater inputs.

Stewart Mill Creek), have contributed 73, 67, and 57 percent of the total yield, with an average of 67 percent.

The average basin yield for the past 20 years from Georgetown Lake is 28,100 acre-feet (3.469×10^7 m^3) per year (Phil Farnes, SCS, Bozeman, Mt, unpublished data). Using the above estimate for groundwater contribution, the average groundwater yield is (0.67 x 28,010) 18,767 acre-feet (2.316×10^7 m^3)/year; the average surface input is 9,240 acre-feet (1.141×10^7 m^3)/year.

The percentage of total surface area between 1 meter elevation contours is shown in Table 8. Sixty-five percent of the total surface area lies above the 6.5 meter depth contour, and the largest interval is that between 6 and 7 meters.

Lake surface elevations (Table 9) were considerably lower during 1973-1975 than in 1981-1982, due to low hydrologic yield and higher industrial use. The maximum surface elevation obtained (Anaconda gage datum) in 1973 was 6427.2 feet. The minimum elevation that winter was 6424.8, a drawdown of 4.7 feet (1.43 m) below maximum stage. In 1974, the maximum surface elevation obtained was 6428.1, as compared to conditions in 1981-82, during which surface elevations remained near 6429.5 during the ice free season. Based on review of Anaconda Company water level records, the reservoir reaches its maximum surface elevation in early July. During the period from 1952-1969, water levels were drawn considerably lower than in recent years, due to greater industrial water use by the Anaconda Company Smelter. For many years, pumping by Anaconda Company was a major source of withdrawal during winter from Georgetown Lake. Water was pumped through the pumphouse on Highway 10A to Silver Lake, stored, then pumped through an aqueduct to Warm Springs Creek, which flows south to Anaconda, where it would then be withdrawn for process water in the smelter or pumped on to Butte for use in facilities there.

Table 8. Area-depth relationships in Georgetown Lake.

Depth Contour (m)	Area (ha)	% Total	Cumulative %
0-1	67.8	5.6	5.6
1-2	70.2	5.8	11.4
2-3	70.2	5.8	17.2
3-4	110.1	9.1	26.3
4-5	124.7	10.3	36.6
5-6	143.5	12.0	48.6
6-6.5	198.5	16.4	65.0
6.5-7	335.2	27.7	92.7
7-8	59.3	4.9	97.6
8+	29.1	2.4	100.0

Table 9. Average seasonal reservoir surface elevations for 1952-1982. Anaconda Company reservoir gage datum. Elevation of spillway, 6429.5 feet.

Year	Summer Ave	Winter Ave	5 Jul	Summer Max	Annual Min	
81-82	6429.4	6429.1	6429.4	6429.5	6427.7	Mar
80-81	29.4	28.8	29.5	29.5	28.4	Mar
79-80	29.5	27.7	29.6	29.6	26.8	Apr
78-79	29.1	28.5	29.3	29.3	27.4	Apr
77-78	29.5	27.7	29.5	29.5	26.9	Apr
76-77	29.0	29.1	29.3	29.3	28.6	Mar
75-76	29.4	28.9	29.4	29.4	27.6	May
74-75	29.5	27.3	29.4	29.7	26.4	May
73-74	27.9	25.9	27.7	28.1	24.8	Mar
72-73	26.6	28.1	27.2	27.2	25.9	Sep
71-72	29.5	28.8	29.3	29.6	27.7	May
70-71	29.5	28.4	29.3	29.6	27.2	May
69-70	29.4	28.1	29.5	29.5	27.2	May
68-69	29.1	28.5	29.2	29.2	27.4	Apr
67-68	29.1	28.4	29.0	29.2	27.4	May
66-67	29.1	26.1	29.1	29.2	25.2	May
65-66	27.1	28.3	27.2	27.2	26.0	May
64-65	28.9	28.4	28.8	29.0	26.4	May
63-64	29.1	28.3	29.1	29.2	27.6	Apr
62-63	29.0	27.8	29.1	29.1	26.8	Apr
61-62	28.8	27.0	28.9	28.9	25.9	Apr
60-61	27.7	27.5	28.2	28.2	26.6	Apr
59-60	28.7	28.4	28.9	28.9	27.2	May
58-59	28.3	28.2	28.1	28.5	26.1	May
57-58	28.9	26.1	28.9	28.9	25.5	Apr
56-57	27.0	25.8	27.1	27.2	24.2	May
55-56	27.7	26.9	26.7	26.9	25.0	May
54-55	28.7	26.9	28.5	29.0	25.9	Apr
53-54	27.4	26.8	27.5	28.7	25.8	Apr
52-53	28.8	26.7	28.7	28.9	26.3	Feb

SOLAR RADIATION

Average total incident solar radiation at Georgetown Lake (latitude 46° 10" N) was calculated for bi-monthly intervals from June through mid-October (Table 10). Total daily incident radiation varied up to 628% within a single 15-day period due to cloud cover. Maximum average daily radiation occurred from 1-15 July and decreased considerably subsequent to 31 August. Monthly averages of daily total incident radiation for alpine sites given by Hutchinson (1957a), shown in Table 11, are similar to values obtained for Georgetown Lake and indicate the general significance of local weather patterns in influencing incident radiation.

Data on light penetration and water clarity in Georgetown Lake are summarized in Table 12. Mean vertical extinction coefficients in 1974 during the ice free season averaged about -0.70, while in 1981, the average was approximately -0.43. Measured at

Table 10. Bimonthly averages for daily total incident radiation (DIR) (cal/cm^2/day) at Georgetown Lake.

Period	Mean DIR	N	s	Range
16-30 Jun	605	12	140	290-773
01-15 Jul	610	14	97	290-760
16-31 Jul	620	19	107	231-780
01-15 Aug	501	9	129	334-628
16-31 Aug	534	11	93	343-610
01-15 Sep	482	12	93	290-569
16-30 Sep	301	16	152	74-465
01-15 Oct	304	2		278-331

Table 11. Monthly means of total incident radiation (cal/cm^2/day) at two alpine localities in Europe (Hutchinson, 1957a).

	Lat. N	Jun	Jul	Aug	Sep	Oct
Zugspitze	47	562	433	509	368	277
Davos	46	621	640	511	468	358

Table 12. Average depth of euphotic zone, 1974 and 1981.

	1974[1]	1981	% Increase
June	7.5	9.4	25
July	6.5	12.0	85
August	6.1	10.0	64
September	6.9	9.7	41
October	10.2	10.4	2

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[1] Calculated from mean vertical extinction coefficients given by Knight (1980).

Station I, the depth of the euphotic zone, defined as the depth below the surface at which 1% of the incident radiant energy in the spectrum from approximately 380-700 nanometers (Ryther, 1956), and roughly equivalent to the maximum depth at which plants can grow, reached a maximum of 12 meters and a minimum of 9.4 meters in 1981. Values obtained in 1981 for light penetration were 2-85 % greater than those observed in 1974. In 1982, water clarity decreased at Station I, and was noticably less throughout the reservoir, vertical extinction coefficients averaging about -0.60.

QUALITY ASSURANCE

General laboratory procedures followed Handbook for Analytical Quality Control in Water and Wastewater Laboratories (EPA, 1972). Reagent grade water was prepared by passing glass-distilled water through three "ultrapure" Barnes ion-exchange column cartridges. Distilled water for standards and blanks was taken directly from the columns. All glassware used in nutrient analysis was acid washed, capped and stored in covered shelves to prevent contamination when not in use. Analytical standards were prepared weekly from analytical reagent grade chemicals dried at 105 C and stored under a dessicator.

	SPIKES				REPLICATES			
	N	MEAN %R	S.D.	RANGE%R	N	MEAN,S-D	S.D.	RANGE,S-D
NH3-N	18	99	13	70-124	20	1.7	2	0-8
NO3-N	19	81	19	43-109	20	1.0	3	0-7
PO4-P	18	100	1.4	96-102	20	0.0	0.0	0-1

TABLE 13. Results of Spikes and Replicate Samples. %R = percent recovery; RANGE%R= range of percent recovery; MEAN,S-D = average differencebetween replicates; S.D. = standard deviation. RANGE,S-D = range of differences between replicates.

	NOMINAL VALUE	ANALYTICAL	%ERROR	%VARIATION
NH3-N	.19	.18	-5%	0.5
NO3-N	.31	.34	+8%	2.6
PO4-P	.031	.029	-6	0.0

TABLE 14. Analysis of EPA Quality Control Samples. N= 2 for each parameter analysed.

Samples were replicated and spiked at a frequency recommended by EPA (1972). Recovery rates were determined and analytical values were adjusted for percent recovery. Quality control results are reported in Table13. Results of Spikes and Replicate Samples, and Table 12 Results of EPA Quality Control Sample Analysis.

Low recovery of nitrate occurred on one occasion. The value of 43% was obtained for both spikes. The standard curve obtained was linear within the analytical range when compared to other standard curves. The low value is probably due to incomplete reduction of nitrate by hydrazine. This stage of the analysis appears to be more variable than cadmium-copper reduction, but is much more convenient when a large number of samples must be analysed with limited personnel. Nitrate data from 1973-75 were corrected for an average recovery rate of 0.80. Recovery of phosphorus was quantitative at a minimum value of 6 micrograms/liter (n=2, %variation = 0). All results are reported as micrograms (ug) per liter or milligrams (mg) per meter cubed. Values less than 10 ug/l for ammonia nitrogen and nitrate nitrogen are below the accepted EPA limits for analytical precision, but were evaluated at stated concentrations for study purposes.

Chlorophyll analyses were run on EPA quality control samples using the B&L Spectronic 88 and duplicated on a Beckman DU spectrophotometer at Montana State University which was optically aligned immediately prior to use. The latter was the same instrument used in previous studies of phytoplankton in Georgetown Lake (Knight, et al, 1975; Knight, 1981). Results obtained by both instruments were within 10 percent when compared. Both gave results about 25 percent lower than the nominal values for the sample. Correction factors were not applied to chlorophyll data for purposes of comparing 1974 and 1981 values or classifying trophic state, as the changes were not of significant magnitude.

CHEMICAL

Alkalinity, pH, and Conductivity

PH, alkalinity, and conductivity showed an annual pattern expected of a shallow, productive reservoir subjected to a long period of ice cover (Tables 15-16). At unenclosed stations pH increased through the summer from around 8.6 in June to 9.5-10 in late August, 1981, reaching a maximum of 10.0 at station V, located in dense macrophyte growth at a depth of about 2 m. A difference of nearly 2 pH units from surface to near bottom was observed at station V, the shallow enclosure control site, at the peak of plant growth, indicating a sharp stratification of primary zones of carbon fixation by plant photosynthesis and carbon recycling by sediment related respiration.

At stations I-III less marked stratification of pH from surface to bottom was observed and pHs obtained were not as high-about 9.5 in August, 1981. Station IV obtained higher pH's than did I-III. attributed to the dense macrophyte stands in that area.

At stations I-V alkalinity decreased from around 2 milli-equivalents (meq) per liter in late June to about 1.5-1.6 in late August, 1981. This represents a condition of undersaturation

Station	I		II-IV		V		E (1-4)		E-5		E-6	
Alk pH	Alk	pH	Alk	pH	Alk	pH	Alk	pH	Alk	pH		
29 Jun 81	1.78	8.4	1.76	8.6	1.69	8.9	1.56	9.0	1.56	9.0	***	***
08 Jul 81	1.72	8.7	1.70	9.0	1.65	9.1	1.90	8.1	1.90	7.9	1.72	8.6
12 Aug 81	1.54	9.1	1.51	9.1	1.48	9.5	2.45	8.3	****	***	1.76	7.8
09 Sep 81	1.60	9.2	1.53	9.4	1.46	9.6	2.58	8.0		9.0	1.80	7.8
22 Sep 81	1.54	9.1	1.52	9.1	1.57	9.4	2.51	8.0		8.1	1.80	7.8
13 Oct 81	1.59	9.1	1.58	9.1	1.57	9.2	2.72	7.9	1.72	8.2	1.79	8.3
24 Nov 81	****	***	1.70	8.4	****	***	****	***	****	***	****	***
30 Jan 82	2.20	7.8	****	***	2.13	7.9	2.55	7.4	2.13	7.9	1.80	7.6
26 Feb 82	2.28	7.7	2.08	7.7	2.23	7.8	2.78	7.7	2.23	7.4	1.80	7.6
26 Mar 82	2.35	7.7	2.13	7.8	2.48	7.7	3.45	7.6	2.48	7.5	2.13	7.8
01 May 82	2.34	7.6	2.05	7.8	2.87	7.4	2.04	7.5	2.87	7.5	2.10	7.7

Station	I		IV		DE1		DE2	
	pH	Alk	pH	Alk	pH	Alk	pH	Alk
09 Jul 82	8.17	2.10	8.43	1.88	****	****	****	****
21 Jul 82	8.45	1.91	8.42	1.95	8.16	1.87	8.36	1.92
28 Jul 82	8.48	1.90	8.67	1.90	8.33	1.80	8.56	1.80
03 Aug 82	8.67	1.88	8.72	1.85	8.36	1.78	8.59	1.79
14 Aug 82	8.46	1.81	8.64	1.73	8.42	1.70	8.56	1.71
28 Aug 82	8.76	1.72	9.02	1.60	8.82	1.60	9.16	1.64
07 Sep 82	8.53	1.65	8.80	1.65	8.73	1.58	9.03	1.61

Table 15. Average values for alkalinity-pH for Georgetown Lake sampling stations. Alkalinity is given in meq/l. Values for E (1-4) and II-IV are arithmetic averages. E2, E3, and E4 were not sampled after 13 October, 1981.

Station	I	II-IV	V	E(1-4)	E-5	E-6
30 Jun 81	187	185	176	164	***	***
07 Jul 81	178	160	175	203	***	184
12 Aug 81	166	164	146	280	***	190
25 Aug 81	164	146	148	262	158	196
09 Sep 81	164	154	172	283	171	202
13 Oct 81	165	162	176	295	180	195
24 Nov 81	178	178	177	***	***	***
30 Jan 82	243	***	240	290	239	207
27 Feb 82	239	207	238	279	243	197
26 Mar 82	228	215	230	250	235	186
30 Apr 82	232	208	205	218	204	218

Table 16. Average specific conductance (umho/cm^2 at 25 C) at sampling stations in Georgetown Lake.

far removed from equilibrium with carbon dioxide in the atmosphere, reflecting the high rates of net primary productivity and the low rate of invasion of CO_2 from the atmosphere (Stumm and Morgan, 1970).

Enclosures 1-4 showed a different pattern of pH, alkalinity, and conductivity changes, due to the dieoff and decomposition of the enclosed macrophytes, which had already obtained standing crops of 80-100 gm/m^2 when the enclosures were put in place. PH decreased from around 8.6 in June to between 7-8.2 in July and remained near that level. Alkalinity also increased to an average of 2.71 meq per liter, reflecting increased respiration from decomposition of dead macrophytes. This represents more favorable conditions for plant growth in terms of carbon availability due to the accompanying increase in free CO_2 (Ruttner, 1960), and may be a factor in the tremendously increased phytoplankton standing crop observed in Enclosures 1-4. Concurrently, dissolved oxygen decreased from around 11 mg/1 to a minimum value of approximately 2 mg/1.

Enclosure 5, which was removed for the installation of clear vinyl inserts to allow increased light transmission to the interior of the enclosure, was reinstalled in August. From 1 September through 13 October, alkalinity increased slightly from an initial value of 1.56 to 1.72 meq/1; however pH declined from 9.0 to 8.2, at which a supersaturation of CO_2 existed relative to total dissolved inorganic carbon. Apparently $CaCO_3$ precipitated earlier was slow to go back into solution as $CaHCO_3$ as sediment respiration added CO_2 back into the aquatic system.

In the two deep experimental enclosures employed in 1982, alkalinities decreased to slightly lower levels than at the control site, obtaining minimums of 1.58 and 1.60 for DE1 and DE2, respectively. The control site, IV-D, obtained a minimum alkalinity of 1.65, the same as station I, however pH were consistently higher at the enclosure site than at station I. Enclosure DE2, which was fertilized with nitrogen and phosphorus, obtained the highest pH observed in 1982, 9.16, as compared to 8.82 for Enclosure DE1, which was not fertilized. and 9.02 for the unenclosed control.

Alkalinity increased at all sampling sites during winter ice cover as respiration released CO_2 into the water. Enclosures 1, 5, and 6 were sampled throughout the winter. Enclosure 1 showed the greatest increase in alkalinity, from 2.55 meq/l on January 30 to 3.45 meq/l on 26 March. Subsequent to 26 March, alkalinity in E-1 appeared to decrease somewhat, although this may have been due to sampling error. Alkalinity in Enclosure 5 continued to increase throughout the winter to a maximum of 2.87 by 1 May. In contrast, station V, the shallow control, showed the effects of profile bound density currents, which would tend to dilute the expected increase in alkalinity (Hutchinson, 1941). The inorganic carbon exported from such shallow areas could be estimated as the difference between total inorganic carbon at station V and Enclosure 5, which amounts to approximately 1.45 mole-equivalents/m^2 (17.4 g inorganic C or 88 g HCO_3). Enclosure 6 obtained a maximum alkalinity of 2.08 on 1 May, an increase from 1.81 meq/l on 30 January.

Comparing conditions in 1981 and 1982 with those observed in 1973 and 1974, significant differences can be observed. Although pH values comparable to those of 1981 were obtained in 1973-74 for areas of dense macrophyte growth, late summer pH values at station I increased from 8.9-9.0 in 1974 to around 9.3 in 1981, indicating an increase in plant growth over that period. This increase must have occurred as macrophytes, as algal standing crops have declined by 100-300 percent . In 1982, the rise in pH at Station I was much slower and did not obtain the high levels observed in 1981. The minimum average alkalinity at station I was 1.65 meq/l on 13 September, as compared to 1.53 meq/l on 12 August, 1981. Alkalinity in the reservoir was considerably higher at sites sampled in 1982 than in 1981, indicating less plant growth or higher community respiration, or both. The fact of reduced macrophytic plant growth during the early part of the growing season in 1982 is verified by the reduction of standing crops of macrophytes by 50-70 percent in shallow areas in June of 1982 versus June of 1981 (Macrophyte Section).

Dissolved Oxygen

Dissolved oxygen concentrations remained near or above saturation at stations I-IV during the late spring and summer sampling period of 1981 (Table 17) except near the sediment where moderate decreases of 2-3 m,g/l were observed. Dissolved oxygen profiles at Station I comparing late spring-early summer data for 1981 and 1982 are shown in Fig. F. In 1981 dissolved oxygen was 1-2 mg/l higher at station I than in 1982, being 13 to 17 percent

Station	I	II-IV	IV[1]	V	E (1-4)[2]	E-5	E-6
30 Jun 81	9.8	****	****	12.8	11.5	****	****
08 Jul 81	8.5	****	****	9.0	5.0	****	****
14 Jul 81	8.5	****	****	8.1	2.9	****	7.9
07 Aug 81	****	****	****	10.4	3.0	****	***
27 Aug 81	8.1	****	****	11.3	6.3	6.1	4.9
02 Sep 81	7.4	****	****	10.8	6.2	4.9	4.2
17 Sep 81	9.6	****	****	12.5	10.7	10.0	5.6
13 Oct 81	8.4	9.6	****	9.6	10.4	8.8	6.2
24 Nov 81	****	9.2	****	****	****	****	****
30 Jan 82	3.5	****	****	2.1	0.2	1.3	5.8
26 Feb 82	1.6	4.5	****	3.9	5.5	3.7	4.5
25 Mar 82	1.7	3.4	****	0.4	1.3	0.4	2.8
01 May 82	1.7	4.6	****	3.1	2.6	3.2	2.6
15 Jun 82	8.4	8.6	****	****	****	****	****
09 Jul 82	7.6	****	8.0	****	****	****	****
21 Jul 82	7.8	****	8.0	****	****	****	****
28 Jul 82	8.2	****	8.9	****	****	****	****

Table 17. Average dissolved oxygen concentrations in mg/l in the water column at stations in Georgetown Lake, 1981-82.

[1] The deep enclosure control site, located in Eccleston's Bay. Similar in depth and macrophytic growth to station IV sampled in 1981.

[2] Average values for 1-4. Enclosures 2,3, and 4 were not sampled after 13 Oct 81.

supersaturated near the surface. Although ice-out did not occur until several weeks later in the spring in 1982, the water column at station I was close to saturation (95-101 percent) by 15 June. According to Hutchinson (1957), physical processes are sufficient to bring this about with the observed time period (three weeks). The supersaturation observed in 1981 is the result of unusually heavy macrophytic growth occuring under the ice in late spring. Although dissolved oxygen at stations I-III declined during the summer of both 1981 and 1982, they remained near saturation when temperature and altitude effects were considered.

Station V, located in a dense stand of Elodea, frequently obtained high levels of supersaturation (125-150 percent). Dissolved oxygen remained high throughout the plant canopy but dropped precipitously within 0.1 meters of the sediment water interface to 1-2 mg/l, indicating the high rates of sediment respiration. The high levels of oxygen production were obtained during diurnal production measurements in the littoral plant beds; 10-12 g O_2/m^2/day during midsummer.

Enclosures 1-4 showed an increase in dissolved oxygen within a week of installation, obtaining maximum concentrations of 164% saturation, but oxygen content declined rapidly after 30 June, decreasing to minimum values on or about 7 July of 2-3 mg/l at the surface and less than 1 mg/l near the sediment. Oxygen concentrations remained depressed for most of August at 4-6 mg/l, then recovered in early September as algal populations increased to

8-10 mg/l at the surface. Daily variation of 2-3 mg/l were observed during community metabolism measurements in September, concentrations being reduced to 5-7 mg/l by early morning. Daily variations of lesser amplitude were observed at Station V, where even in early morning measurements oxygen remained above saturation.

Enclosure 6, which was installed near the dam at the 6.5 meter contour, showed a steady decline in dissolved oxygen, having limited turbulent exchange and probably being light limited. Photometer measurements showed that available light decreased rapidly at depths greater than 3 meters, due to the small diameter of the enclosure and the opaque walls. Oxygen concentrations stabilized at 60 to 80 percent saturation until sampling was temporarily discontinued in October.

On 24 November, dissolved oxygen profiles were determined at stations II and III. Air temperature was -1 degree C, water temperature was 0.5-1 degree C. The reservoir was partially frozen over with a thin sheet of ice which extended from the dam to a line connecting Piney Point to the shoreline along Highway 10A just north of the mouth of North Fork, Flint Creek. Oxygen concentrations were between 9.1 and 9.3 mg/l, increasing slightly with depth. The average concentration was 9.1, which represents 82 percent saturation at the surface. The 18 percent saturation deficit is evidence of intense respiratory activity and high biochemical oxygen demand caused by senescing and decaying macrophyte growthy, which had maintained high standing crops in some areas into late October.

Sampling was discontinued until 30 January, 1982. At that time severe oxygen deficits had developed at all stations sampled (Figures F-K). Oxygen concentration continued to decline at station I through 1 May, although some evidence of recovery was present subsequent to 26 March. Shallow littoral areas are usually considered the greatest oxygen sinks, due to high sediment oxygen demand, high sediment surface:water volume ratios and consequent frequent turbulent renewal of water at the sediment-water boundary. However, between 30 January and 26 February, 1982, dissolved oxygen increased in Enclosures 1 and 5, by 4.87 g/m^2 (0.174 g/m^2/day) and 2.42 g/m^2 (0.089 g/m^2/day), respectively. During the same period station V showed an increase of dissolved oxygen of 2.45 g/m^2 (0.089 g/m^2/day). This rate can be taken to express net community oxygen production, as the enclosures were sealed at the top and bottom, thus preventing any exchange of dissolved gases, other than through the ice. These rates are higher than any estimates of net production reported for Georgetown Lake by Knight (1980) during the winter of 1974-1975, and show that oxygen metabolism at station I does not represent whole-lake events. The high chlorophylls and absence of macrophytes at these stations indicate that algae, either planktonic or benthic, are responsible for the oxygen production.

Net community oxygen uptake under the ice was estimated for Enclosures 1, 2, and 6, and stations II-IV and V. Based on measurements made 24 November, concentrations were assumed as 9 mg/l at these stations, except for E-6, which was assumed to be 6 mg/l

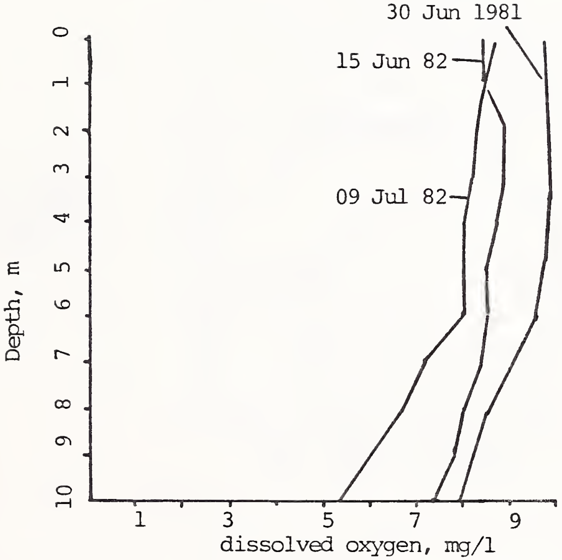

Fig. F. Dissolved oxygen profiles at station I, June and July.

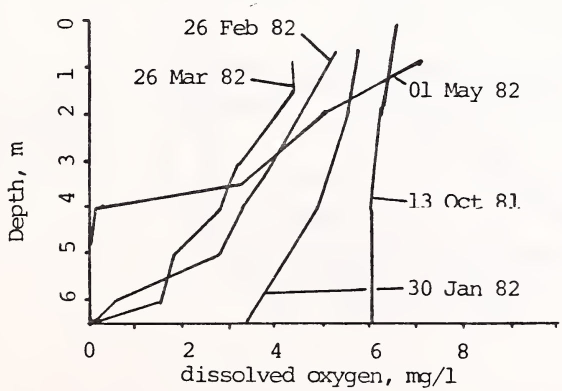

Fig. G. Average dissolved oxygen profiles at stations II-IV during ice cover, 1981-1982.

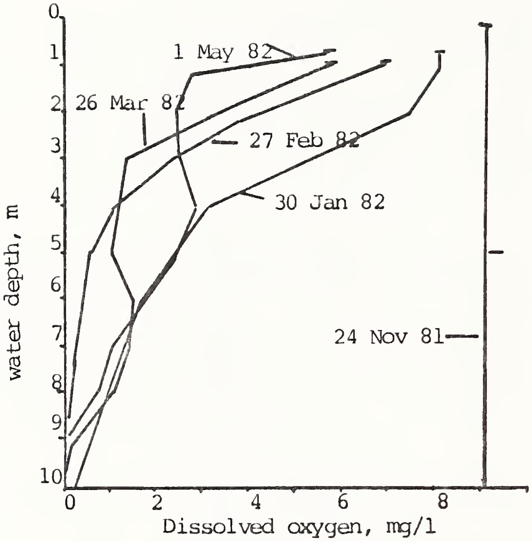

Fig. H. Dissolved oxygen profiles at station I, winter, 1981-1982.

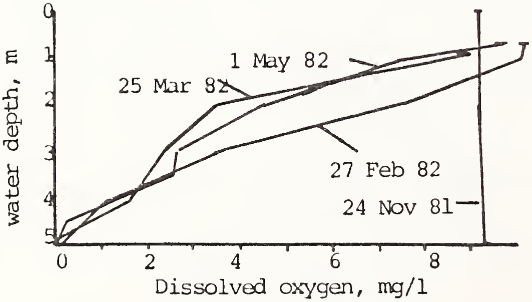

Fig. I. Composite dissolved oxygen profile for stations II-IV, winter, 1981-1982.

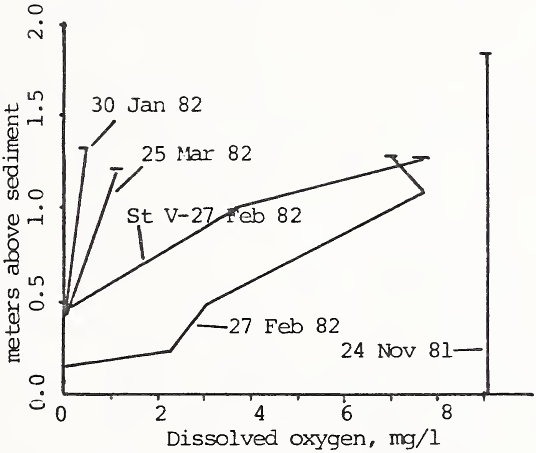

Fig. J. Dissolved oxygen profile at Enclosure 1, winter, 1981-1982.

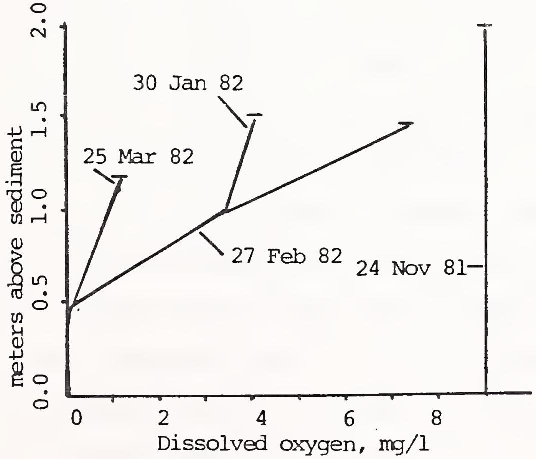

Fig. K. Dissolved oxygen profile at Enclosure 5, winter, 1981-1982.

average. This assumption seems reasonable in light of the high transparency of the thin ice cover, low temperature of the water, and short time the surface had been frozen over (7-10 days).

Four independent estimates of net oxygen consumption at Enclosures 1 and 5 gave a mean uptake rate of 0.16 g O_2/m^2/day (s.d. = 0.015; r = 138-166). These estimates encompassed the period of ice cover from 24 November to 26 March, varying only slightly between different dates and enclosures. The period from 30 January to 26 February was not included, as positive oxygen production was obtained. The same uptake rate was obtained for Station V from 24 November to 30 January and 0.060 g O_2/m^2/day from 27 February to 26 March.

At Stations II-IV, calculation of net oxygen consumption varied only slightly between early and late winter. Prior to 27 February, net community oxygen consumption was estimated at 0.272 g/m^2/day. From 27 February-1 May, the consumption rate was estimated at 0.322 g/m^2/day. During the period from 27 February to 26 March, heavy snow accumulations of up to 16 inches blocked much of the incident light, creating conditions for maximum oxygen depletion. The estimate of 0.32 g O_2/m^2/day is considered the most reasonable estimate of average oxygen uptake in the upper lake basin. Mathias and Barica (1980) give a mean oxygen depletion rate for shallow, eutrophic prairie lakes of 0.23 g O_2/m^2/day, with maximum observed rates about 0.40 g/m^2/day. The Georgetown Lake basin falls in the upper end of this range, and is clearly eutrophic by this criteria. This rate predicts that the most critical period of oxygen stress will be in March, which agrees with observations, as minimum values were obtained in March, with recovery apparent in late April. Oxygen data collected over a period of several years by the Montana Department of Fish, Wildlife, and Parks (unpublished data) shows the same pattern, with minima occurring in middle to late March, and recovery by late April. This rate also indicates the possibility of winterkill of fish due to oxygen stress should prolonged heavy snow cover and cloudy weather occur during late March and April under a drawdown condition. Obviously, the maintenance of positive oxygen concentrations is dependent on periods of thawing and clear weather which allow sufficient light penetration for positive net photosynthesis and inputs from ground water, of which several major areas are known. One is located near the pumphouse, where a large spring flows in at a concentration of about 7-8 mg/l. Another similar spring is located in the Denton's Point Marina. These two areas provide refuges for oxygen-stressed fish during critical period of oxygen depletion during extremely heavy snow cover. Other smaller spring inputs are probably present throughout the reservoir basin.

From 27 February through 26 March, oxygen consumption in Enclosure 6 was estimated at 0.15 g O_2/m^2/day. During this time, a sharp stratification was established at the 3 meter level, below which oxygen declined abruptly. The uptake rate was calculated based on changes from 3 meters to the bottom. The range of oxygen uptake rates calculated for Enclosure 6 was 0.080 to 0.310 g O_2/m^2/day.

The maximum rate was estimated from 24 November through 30 January, and may be an over-estimate.

The apparent low uptake rates observed for Enclosures 1 and 5 may be a result of oxygen limitation of sediment-related metabolism, which has been proposed by Barica and Mathias (1980). Or they may be the result of significant oxygen production in these areas, as was observed between 30 January and 26 February. The same reasoning may be applied to Station V, although mass transfer by density currents Hutchinson, 1957, 1941) and profile bound currents (Hutchinson, 1957) are also likely explanations. It should not be inferred that these values represent actual respiration rates in littoral areas, or that respiration in shallow littoral areas is less than in deeper areas; however, the data do demonstrate that under certain conditions the littoral zone may act as an oxygen source rather than a sink during ice-cover. In this case the oxygen production observed was certainly by algae, as no standing macrophytes were present before or after ice cover.

If changes in pH and alkalinity are used to estimate respiratory metabolism, Enclosure 5 exhibited a net carbon metabolism of 0.111 g C/m^2/day from 30 January through 26 March. If aerobic metabolism were responsible for oxidation of this organic material, the oxygen consumption rate would be 0.296 g O_2/m^2/day, which is approximately that obtained for Stations II-IV, and suggests a significant component of anaerobic metabolism. The same calculation for Enclosure 1 gives an estimate of net carbon respiration of 0.238

g C/m^2/day, equivalent to 0.762 g O^2. Net carbon oxidation for Enclosure 6, estimated from changes in alkalinity, averaged 0.246 g C/m^2/day, equivalent to 0.656 g O_2/m^2/day. This ratio of oxygen uptake to carbon mineralization also indicates a large component of anaerobic metabolism in regeneration of inorganic carbon.

A significant question to be answered during the 1981-82 study concerned macrophytic oxygen production during winter. Knight, et al (1976), calculated a hypothetical oxygen budget based on light/dark bottle measurements of planktonic metabolism. Those measurements ranged from -0.01 to -5.56 g O_2/m^2/day, with a mean of -1.51. This estimate was subsequently changed (Knight, 1980) to a mean value of -0.85 g O_2/m^2/day. This latter rate is approximately 8 times the average winter plankton respiration rate for eutrophic lakes given by Mathias and Barica (1980), 2.5 times the average observed rate of depletion in the upper lake basin during winter, 1981-82, and over 5 times as great as the average oxygen depletion rate obtained for the planktonic community in Enclosure 6. To explain this discrepancy, Knight invoked oxygen production by macrophytes, which he proposed was sufficient to provide the difference. Presumeably the major oxygen producer would be Potamogeton praelongus, which is a perennial and may be seen green and apparently viable under the ice cover. Elodea may also be responsible for significant winter oxygen production, as considerable standing crops accumulate during late spring of some years, such as 1981, in which standing crops of Elodea were 50-80 g/m^2 in early June.

To determine if such rates of oxygen production were present, several diurnal measurements of community metabolism of unenclosed communities were made through the ice in April, 1982. Two areas were sampled; one near the Grassy Point access site at the 4 meter contour, a location known to have dense stands of Potamogeton praelongus. The other sampling site was near Red Bridge access, at the 7 meter contour, which is known to be free of macrophytes and was assumed to be isolated from macrophyte effects over 24 hours. Measurements at the Red Bridge site were confined to the upper 4 meters of the water column, to minimize sediment influence and bias due to additional respiration in the water column below the mean depth of the reservoir. Clear days were selected for measurements to maximize potential photosynthesis. At this time, there was no snow cover on top of the ice, which was approximately 0.8 m thick. Between 25 and 29 April, net community oxygen production at the Grassy Point site was -1.13 g O_2/m^2/day. Community oxygen consumption was estimated at 2.46 g O_2/m^2/day. Gross daytime oxygen production was 1.33 g/m^2/day.

At the Red Bridge site, gross oxygen production was 2.34 g O_2/m^2/day. Community oxygen uptake was 0.37 g O_2/m^2/day. Net oxygen production was 1.94 g O_2/m^2/day. The plankton respiration rate was equivalent to approximately 0.012 g O_2/m^3/day, which agrees closely with the value of 0.01 g

O_2/m^2/day given for average winter planktonic respiration rates in eutrophic prairie lakes by Mathias and Barica. Applying this value to community respiration at the Grassy Point Site gives a benthic respiration estimate of 2.46-0.30 = 2.16 g O_2/m^2/day. Benthic respiration at that particular time accounted for 88% of the total community respiration measured at the Grassy Point site.

One set of measurements do not prove that macrophytes are not the major oxygen producers. However, these measurements agree with the observed oxygen profiles, which indicate that the benthic macrophyte community is essentially a winter oxygen sink, and not a major oxygen source to upper layers. In situ measurements of the photosynthetic potential of macrophytes under the ice (Boylen and Sheldon, 1976) indicate that potential oxygen production is about 10% of summer rates per unit biomass. They also found that substantial reductions in biomass occurred during ice-cover. Considering the potential oxygen production observed, their results provide additional evidence that the rates of oxygen production subscribed to macrophytes in Georgetown Lake are not likely to exist.

In view of the observed increases of oxygen in the littoral zone at station V, the rates of oxygen consumption in macrophyte communities near Grassy Point in April, and other evidence presented, I must conclude that the macrophyte communities, although producing some oxygen during winter ice-cover, are not the major source of oxygen input during winter stagnation, and that a well planned harvesting program which eliminated up to 50 % of the major macrophyte species would probably not cause a deterioration of the winter dissolved oxygen conditions in Georgetown Lake.

Further evidence of underestimation of oxygen production by phytoplankton during the winter is found in the chlorophyll distribution in the winter of 1981-1982, during which Station I consistently had chlorophyll concentrations of 10 to 25 % of those observed at Stations II-V. It must be concluded thata the data and calculations of Knight, et al (1975) and Knight (1980) pertaining to whole lake oxygen budgets are invalid and that there is no evidence for macrophytes as a major source of oxygen in Georgetown Lake during winter.

Phosphorus

Nutrient chemistry in Georgetown Lake during 1973-75 has been discussed by Knight, et al, 1976, Knight, 1980, and Foris, 1976. In the summer of 1981, ortho-phosphorus (= soluble reactive phosphorus) was undetectable from late June through July at stations I-IV, then increased to a maximum of 5 ug/l on 12 August at Station IV (average 3 ug/l for stations I-III). Ortho-phosphorus then decreased back to undetectable levels in September before increasing slightly to 3 ug/l on 13 October. Dissolved organic phosphorus (= dissolved unreactive phosphorus) composed a significant fraction (55%) of the total phosphorus through October sampling, averaging about 10 ug/l at stations I-III and 12 ug/l at Station IV. Bieleski (1973) has suggested that some algae and aquatic vascular plants exhibit a significant leakage of organic phosphorus, while able to take up inorganic phosphorus to very low levels, less than 0.1 uM. The equilibrium concentration of organic phosphorus was indicated to be approximately 0.3 uM, which would be about 8-10 ug/l. The

Station	I				II				III				IV			
	I	D	T	P	I	D	T	P	I	D	T	P	I	D	T	P
17 Jun 81	0	**	20	**	0	**	20	**	0	**	21	**	0	**	34	**
30 Jun 81	0	13	20	07	0	12	18	06	0	12	26	14	0	12	33	21
15 Jul 81	0	13	24	11	0	11	26	15	1	13	21	8	0	14	24	10
28 Jul 81	1	14	17	2	0	14	18	4	0	14	14	0	3	21	29	5
12 Aug 81	1	13	19	5	3	9	14	2	3	10	17	4	5	12	20	3
25 Aug 81	1	5	17	11	2	8	21	11	1	4	14	10	2	3	20	15
09 Sep 81	0	8	16	8	0	9	10	1	0	7	13	6	0	12	22	10
13 Oct 81	3	4	19	12	3	5	17	11	3	5	19	11	3	5	34	26
24 Nov 81	***************				4	6	17	7	3	5	18	10	***************			
30 Jan 82	5	3	14	6	*****************				*****************				***************			
27 Feb 82	4	9	19	6	0	10	14	4	0	10	17	7	0	11	17	6
26 Mar 82	5	4	15	6	2	4	13	7	0	6	12	6	2	4	20	14
01 May 82	2	7	16	7	0	8	15	7	0	7	16	9	0	8	17	9
17 Jun 82	2	6	26	18	2	**	24	**	3	**	23	**	***************			

Table 18. Average phosphorous concentrations at sampling stations in Georgetown Lake in 1981-82. Concentration in ug/l (mg/m^3.) I = inorganic P; D = total unreactive dissolved phosphorous;
T = total phosphorous; P = particulate phosphorous (total less total dissolved).

Station	V				E (1-4)				E-5				E-6			
	I	D	T	P	I	D	T	P	I	D	T	P	I	D	T	P
16 Jun 81	0	**	20	**	***************				***************				****************			
29 Jun 81	0	14	28	14	0	24	27	3	***************				****************			
08 Jul 81	1	************			1	************			***************				****************			
15 Jul 81	0	15	22	7	0	29	37	8	***************				0	18	23	5
28 Jul 81	1	14	20	5	2	28	36	6	***************				3	17	22	5
04 Aug 81	2	10	27	15	9	19	36	8	***************				****************			
12 Aug 81	5	12	59	42	13	13	98	72	***************				5	12	22	5
25 Aug 81	9	10	36	17	35	38	151	78	6	8	54	40	6	7	20	7
09 Sep 81	6	10	41	25	56	50	224	118	14	20	66	32	5	14	21	2
22 Sep 81	5	13	46	33	18	45	209	146	1	31	53	21	4	15	27	8
13 Oct 81	6	8	40	26	11	21	61	29	5	19	40	16	5	10	24	9
30 Jan 82	4	2	22	16	14	6	101	81	3	6	64	55	5	5	13	3
27 Feb 82	0	10	19	9	3	11	37	23	0	11	38	27	6	12	22	4
26 Mar 82	2	5	30	23	5	10	43	28	2	6	31	23	4	6	16	6
30 Apr 82	2	11	43	30	3	11	46	32	0	14	47	33	2	8	18	8
15 Jun 82	2	**	35	**	2	**	74	**	***************				****************			

Table 19. Average phosphorous concentrations in ug/l (mg/m^3) for sampling stations in Georgetown Lake, 1981-82. I = inorganic phosphorous; D = dissolved unreactive phosphorous; T = total phosphorous; P = particulate phosphorous (Total less total dissolved).

concentration of dissolved organic phosphorus in Georgetown Lake may be due to phosphorus leakage from macrophytes or algae. Particulate phosphorus averaged 7.4 ug/l at stations I-III, and 13.1 at Station IV, comprising 39% of the average total phosphorus. Particulate phosphorus showed a definite decreasing trend from July until 25 August. when concentrations increased to an average of 12 ug/l. In September, particulate phosphorus declined slightly, but increased in 13 October samples to an average of 13 ug/l, biased by the high value at station IV (26 ug/l.)

Average total phosphorus fluctuated around 20 ug/l throughout the summer of 1981 at Stations I-IV. From 17 June through 15 July increases in total phosphorus at stations I and II were balanced by decreases at stations III and IV, indicating a relatively steady state of phosphorus in the water column outside the shallow littoral areas. Subsequent to 15 July, particulate and total phosphorus declined rapidly at stations I-III, while station IV declined after 29 July. This represents a net loss of approximately 10 ug/l, or 66 mg/m^2. Although internal phosphorus loading has been attributed to heavy macrophyte growths through phosphorus leakage and obviously under certain conditions can cause such phenomena (catastrophic die-off of macrophytes as observed in Enclosures 1-4), it does not appear that macrophytes were a source of internal loading above what may be an equilibrium concentration of dissolved organic phosphorus in the summer growing season of 1981.

The same trends in phosphorus concentrations in the water were evident for the summer of 1982, although not to such a marked degree, possibly due to reductions of early summer macrophyte standing crops in shallow areas of the reservoir by 60-70 percent. The average total phosphorus concentration at station I was 20 ug/l from 17 June through 7 September. The average total phosphorus concentration at station IV was 21 ug/l.

Although total phosphorus concentrations during the summer of 1981 were higher at station V than at stations I-IV, particularly subsequent to 4 August, the phosphorus mass per unit of sediment area was often greater at station I because of the greater water volume:unit area ratio. On 12 August, station V had 112 mg P/m^2; station I, 190. Station II had 84 mg/m^2, and station III, 102. Enclosure 6, which was located near the dam on the 6.5 meter contour in an area uncolonized by macrophytes, obtained a total phosphorus mass of 132 mg/m^2 (average concentration 22 ug/l) on the same date. Thus it does not appear necessary to postulate export of phosphorus from shallower littoral areas of heavy macrophyte growth to account for phosphorus supplies to areas in Georgetown Lake which are not subject to macrophyte colonization. This suggests a normalizing process (sedimentation) which would tend to equilibrate chemical conditions in surficial sediments. Garrison (1976) found some evidence of this in his analysis of Georgetown Lake sediments. In addition Enclosure 6 exhibited average concentrations of dissolved phosphorus equal to or greater than those observed at stations I-V, indicating that the concentration of dissolved organic phosphorus may be controlled by influences other than benthic macrophytes.

Golterman (1980) has suggested that the average annual phosphorus concentrations in lake water tend toward a constant function of the average sediment concentration and retention time, under steady state conditions. This hypothesis may conflict with the widely accepted mechanism of phosphorus control by the ferric/ferrous iron-phosphorus complex, which is mediated through oxygen conditions in the water (Hutchinson, 1957), although not necessarily, as presumeably dissolved organic and particulate phosphorus are not subject to control by the ferric phosphate solubility product. The phosphorus nutrient budget for Georgetown Lake (discussed in a following section) indicates that Georgetown Lake may be approaching a steady state relative to phosphorus income/outgo, thus phosphorus concentrations should be relatively stable on an annual basis. Phosphorus data collected in the summer of 1975 by EPA during the National Eutrophication survey support this conclusion, as the average total phosphorus concentration obtained was 23 ug/l (s.d. 6; r = 18-31) for two sampling sites and two sampling dates, as compared to 20 ug/l for 1981-82 and 31 ug/l during June-September, 1974-75 Garret, 1983).

Enclosures 1-4, in which most macrophyte growth (99%) died during the summer, exhibited large increases in phosphorus through late September, obtaining a maximum average of 224 ug/l on September 9. This was 5-10 times greater than other stations, and is attributable to decay of macrophytic vegetation, representing a net release of 400 mg P/m^2 of lake bottom. Assuming an approximate standing crop of 100 g macrophyte biomass, mostly Elodea, which has a mean phosphorus concentration of 0.30 % in samples from Georgetown Lake, macrophyte decomposition could have accounted for 300 mg/m^2 of the phosphorus released in the enclosures. These extremely large increases in phosphorus were accompanied by increases in algal chlorophyll up to 50 ug/l.

The distribution of phosphorus forms in Enclosures 1-5 and station V is shown in Fig L. All forms of phosphorus increased in Enclosures 1-4, with the largest increases occurring as particulate phosphorus. Inorganic phosphorus also increased significantly, obtaining maximum levels on 9 September, which corresponded with the peak concentrations of algal chlorophyll. Subsequent to 22 September, total phosphorus in Enclosures declined rapidly from 209 ug/l to 61 ug/l, representing a loss from the water column of approximately 280 mg/m^2. This coincides with a temperature decrease from 11.5 to 6 degrees C. Stauffer (1980) has suggested that temperature strongly affects the release of phosphorus from sediments under oxic conditions by influencing invertebrate activity as well as microbial metabolism.

Enclosure 5, the "windowed" macrophyte enclosure, was removed in July for the installation of clear vinyl inserts to allow more light into the interior. After it was replaced, phosphorus concentrations increased slightly above those observed at station V, but the difference in means was not significant in an unpaired t-test. Particulate and dissolved phosphorus were the major components of total phosphorus at station V and Enclosure 5, with inorganic phosphorus ranging from 0-14 ug/l. The non-significant difference in phosphorus in Enclosure 5 and station V leads to a conclusion that phosphorus released in protected littoral areas during the summer growing season is not exported to other parts of the reservoir. This may not represent actual conditions for other more exposed littoral areas of high macrophyte growth, which are subjected to considerably more turbulence than the experimental site. All forms of phosphorus were present at station V and Enclosure 5 at higher concentrations than at stations I-IV from 12 August through 13 October, 1981. During June and July, all forms of phosphorus were present in approximately the same concentrations as were found at the deeper stations. The rise in phosphorus as macrophyte growth and temperatures increase seems to indicate mobilization of phosphorus from the littoral zone, which surely occurs in shallow macrophyte beds exposed to strong wave turbulence. The distribution of sediments, of which the greatest accumulations were found in protected areas and least were found in exposed areas, also supports this conclusion.

Through the winter, the average total phosphorus concentrations at stations I-IV decreased slightly, to a mean of 16 ug/l on 1 May, 1982. At station I, the only site at which stratified samples were collected, concentrations very near the sediment increased sharply .

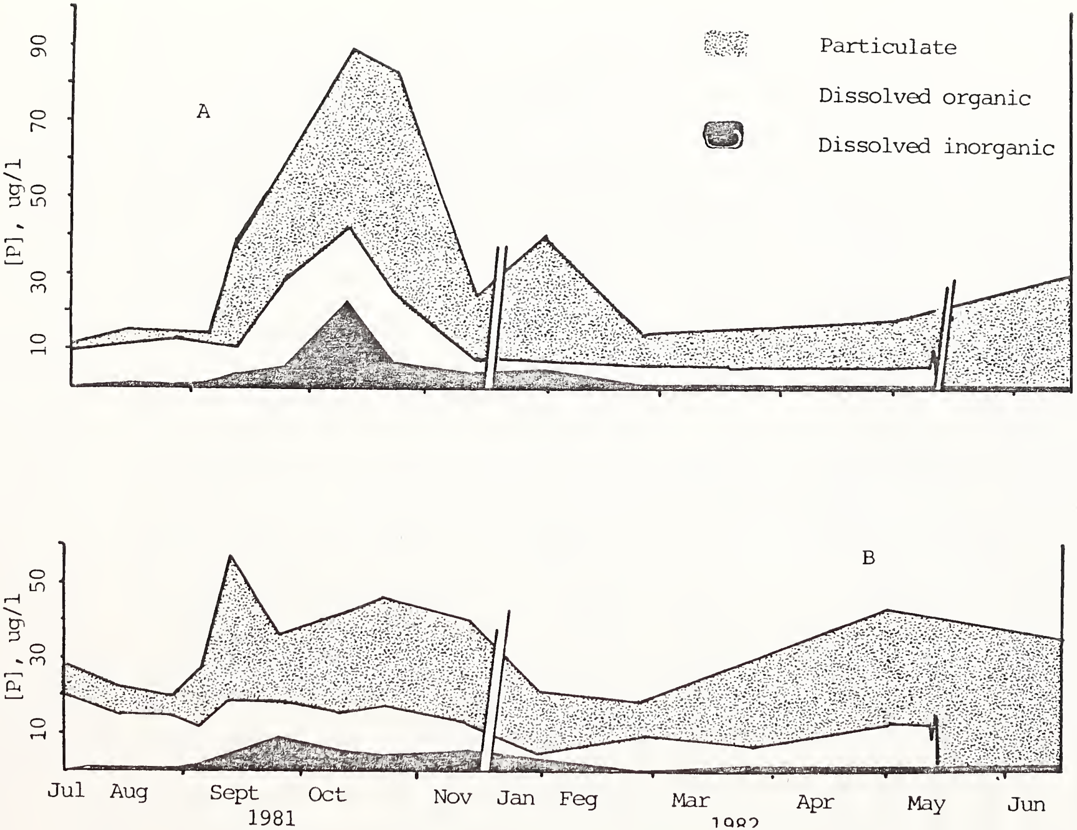

Figure L. Distribution of aquatic phosphorus forms in Enclosures 1-5 (A) and Station V (B). Concentrations in ug/l.

Particulate and dissolved fractions decreased during winter, while inorganic phosphorus increased slightly at station I (range 2-5), although it remained very low in depth-integrated samples at stations II-IV (range 0-2).

At station V total phosphorus decreased in early winter to levels observed at stations I-IV, then steadily increased throughout the winter to a maximum of 43 ug/l on 30 April. This compares to 46 ug/l in Enclosure 1 and 47 ug/l in Enclosure 5 on the same date. Similar trends were observed for total phosphorus in the two shallow enclosures sampled through the winter, as concentrations in both decreased in early winter, then increased through 30 April. The highest concentrations of inorganic phosphorus were observed in Enclosure 1 (3-14) and Enclosure 6 (2-6). Preconditioning of the sediment during the previous summer may have had some influence on the subsequent release of inorganic phosphorus, as it remained very low at station V and Enclosure 5, neither of which were enclosed through the summer. Enclosing the sediment and subjecting the system to reduced oxygen tensions may have affected the sediment water interface, facilitating release of inorganic phosphorus, although the contained waters were well oxygenated on 13 October. The similarity of concentrations in the three shallow sites on 30 April tempts a hypothesis of equilibrium between water and sediment, but may be an artifact of sampling. However, the similarity between concentrations in Enclosure 6 and stations I-IV also indicates the possibility of a steady state relationship which tends to normalize fluctuations.

Subsequent to 30 April, Enclosure 5 was not sampled, as it was damaged during the ice break-up. Enclosure 1 was sampled 15 June, 1982, at which time total phosphorus had increased to 74 ug/l. Water temperature had increased to 12 degrees C, dissolved oxygen was 10.5 mg/l to a depth of 1.5 meters. Inorganic phosphorus was 2 ug/l, comprising 3 % of the total. These results support recycling of phosphorus by invertebrate activity under oxic conditions. Although inorganic phosphorus was low, algal chlorophyll was 12.04 ug/l, which would indicate that some of the organic phosphorus was available for algal growth.

Nitrogen

Inorganic nitrogen concentrations during the summer of 1981 were similar to those found in 1973-75, with the exception of EPA samples collected during the summer of 1975. Nitrate (Table 20) remained undetectable through most of the summer in 1981, obtaining a maximum concentration of 4 ug/l at stations I-IV on 29 June. In the experimental enclosures, nitrate was undetectable in all but 2 samples, obtaining maximum concentrations of 4 ug/l on 29 June, 1981. Subsequent to 15 July, nitrate was not detected in any samples from the lake until after freeze-up. The same general pattern occurred in 1974, with the exception of a slight pulse of nitrate detected on 12 August, when the average concentration at station I was 4-5 ug/l. In 1973, however, nitrate increased from very low levels (estimated 1-2ug/l) during July and early August in samples from station I to an

	I	II	III	IV	V	E(1-4)	E-5	E-6
17 Jun 81	0	0	0	0	0			
30 Jun 81	4	3	4	4	4	4		
15 Jul 81	2	2	2	2	0	0		2
28 Jul 81	0	0	0	0				0
12 Aug 81	0	0	0	0	0	0	0	0
25 Aug 81	0	0	0	0	0	0	0	0
09 Sep 81	0	0	0	0	0	0	0	0
22 Sep 81	1	0	0	4	0	0	0	0
13 Oct 81	0	0	0	0	0	0	0	0
09 Nov 81		0	0					
30 Jan 82	5				0	0	0	1
27 Feb 82	4	1	1	1	1	4	4	3
26 Mar 82	9	10	4	3	5	4	3	3
01 May 82	31	7		4	1	6	0	6
15 Jun 82	2	2	2	2	2	2	2	2

Table 20. Average nitrate concentrations at sampling stations in Georgetown Lake. Concentration in ug/l.

average concentration of 6-8 ug/l on 28 August, and remained detectable at station I at concentrations ranging from 7-13 ug/l distributed throughout the water column until December.

During the winter, nitrate increased at Station to an average concentration of 31 ug/l at station I on 30 April, 1982. At this time, the highest concentrations occurred just under the ice. Nitrate concentrations during the winter were higher at station I than at stations II-IV, which obtained a maximum concentration of 10 ug/l at station II on 25 March. In Enclosures 1, 5 and 6, nitrate remained low throughout the winter (less than 5 ug/l). Nitrate at station V also remained very low, obtaining a maximum concentration estimated at 5 ug/l on 26 March.

The low concentrations obtained for nitrate in lake samples, compared with concentrations obtained for Stewart Mill Creek up to 100 ug/l and samples obtained for small shoreline springs up to 170 ug/l, raises the possibility that some plants in the reservoir may be obligate nitrate users, or that the aquatic flora in general may be nitrate-starved. In 1975, samples collected in July and September by EPA under the National Eutrophication Survey contained averages of 20 and 20 ug/l nitrate, respectively. EPA also obtained average concentrations for ammonia nitrogen of 20 and 20 ug/l, respectively. However, algal assay procedure indicated nitrogen limitation.

Ammonia nitrogen concentrations are shown in Table 21. Patterns of ammonia distribution at station I were very similar to those observed in 1974, concentrations gradually increasing from a June minimum to maximum concentrations in September (Table 21). Station IV obtained the highest NH_3 concentration of the deeper stations, 41 ug/l in September. NH_3 concentrations increased rapidly in Enclosures 1-4 subsequent to macrophyte die-off, reaching a maximum of 260 ug/l (494 mg/m^2) on 9 September. NH_3 concentrations then rapidly decreased in Enclosures 1-4, being 99 ug/l (188 mg/m^2) on 22 September.

In Enclosure 5, NH_3 concentrations increased from 13 ug/l (24.7 mg/m^2) to 405 ug/l (770 mg/m^2) between 25 August and 09 September. At the same time, station V showed an increase in NH_3 from 14 to 25 ug/l (48mg/m^2), and Enclosure 6, an increase to 21 ug/l (137 mg/m^2). From results in Enclosure 5, it appears that bio-activity in littoral communities is a major source of NH_3 to the plankton, and may be a key factor in triggering the observed late summer algal pulse.

During ice cover, NH_3 incresed through the winter at stations I-III, obtaining a maximum concentration of 110 ug/l at station I on 26 March. Again, concentrations were higher at station I than at stations II-IV, and concentrations increased with depth, the highest concentrations being observed just above the sediment. In Enclosures 1 and 5, NH_3 increased through April to maximum concentrations of 232 and 318 ug/l (190 and 260 mg/m^2) respectively. Enclosure 6 showed a steady increase in NH_3 through April, to a maximum concentration of 81 ug/l (467 mg/m^2). It appears the potential

Station	I	II-III	IV	V	E (1-4)	E-5	E-6
17 Jun 81	0	2	0	0	**	**	**
29 Jun 81	2	6	11	0	**	**	**
15 Jul 81	6	4	2	0	1	**	2
28 Jul 81	3	2	3	1	2	**	10
04 Aug 81	6	8	7	8	26	**	13
25 Aug 81	0	1	2	14	3	13	5
09 Sep 81	14	5	10	25	260	405	16
22 Sep 81	9	6	41	9	99	17	21
24 Nov 81	**	6	**	**	**	**	**
30 Jan 82	94	**	**	6	174	25	42
27 Feb 82	92	37	38	0	64	15	46
25 Mar 82	110	38	30	26	198	20	69
30 Apr 82	81	61	26	172	232	318	81
15 Jun 82	0	0	0	0	0	**	**

Table 21. Average NH_3-N concentrations at sampling stations in Georgetown Lake. Concentration in ug/l.

release of NH_3 is as great in areas not colonized by macrophytes as in the littoral macrophyte zone, and that NH_3 release is limited by other factors, most likely the presence of oxygen (Mortimer, 1971), which was absent from the deeper strata of Enclosure 6 during late winter, while primary production of oxygen in Enclosures 1 and 5 was considerable, and oxygen was measureable to within 0.1 meters of the bottom.

In June of 1982, NH_3 was rapidly removed from the free water to non-detectable levels by 15 June. Subsequently, NH_3 remained very low through July and August before beginning to increase again in September. This consistent pattern of NH_3 increase in late summer, accompanied by a phytoplankton pulse, then a marked increase through the winter as decomposition processes become dominant, followed by rapid disappearance in the spring, seems to indicate a general condition of nitrogen limitation of phytoplankton, which agrees with results of EPA bioassay (EPA,undated/a).

Total kjeldahl nitrogen concentrations in summer 1981 (Table 22) were 40-300 % less than those observed in 1973-74 (Knight, 1980), and approximtely 50% less than those obtained during the National Eutrophication Survey in 1975. There are several possible reasons for this, which probably acted collectively to cause the observed reduction. The winter of 1980-81 was mild, with an unusual number of clear days; snow accumulations were slight. This resulted in abundant early macrophyte growth, which could remove NH_3 nitrogen rapidly from the water prior to ice off, either by uptake or reducing

Station	I	II-III	IV	V	E (1-4)	E-5	E-6
16 Jun 81	247	183	476	394	***	***	***
30 Jun 81	154	226	***	244	206	***	202
09 Jul 81	***	***	***	226	239	339	209
17 Jul 81	245	186	189	109	265	246	126
29 Jul 81	70	139	160	122	130	***	67
12 Aug 81	88	***	100	67	155	***	56
25 Aug 81	163	***	***	150	230	211	151
09 Sep 81	176	225	199	159	331	534	***
22 Sep 81	240	131	276	156	486	209	237

Table 22. Total Kjeldahl Nitrogen (including NH_3) at stations in Georgetown Lake in 1981. Concentrations in mg/l.

NH_3 release by increasing dissolved oxygen concentrations. Also, the mild spring may have resulted in reduced macrophyte mortality, and decreased regeneration of NH_3 during winter stagnation. Standing crops of macrophytes in June were estimated to be 75-100 g/m^2, as compared to 0-10 g/m^2 in June of 1974. This unusually heavy macrophyte growth continued throughout the summer, accompanied by low standing crops of phytoplankton (measured as cell volume and chlorophyll "a") and increased transparency.

Also, nitrogen-fixing blue green algae, which were extremely abundant in 1973, and occurred in bloom densities in 1974 and 1975, were almost non-existent in the phytoplankton community during 1981, removing another potential source of organic nitrogen from the reservoir.

The low organic and inorganic nitrogen concentrations observed in 1981 and 1982 resulted in a decrease in the N:P ratios during the summer to a minimum of about 10:1, as compared to ratios observed by Knight (1980) of greater than 20:1 during the summer. N:P ratios were much greater under the ice and in the macrophyte enclosures, 1-5, in which both nitrogen and phosphorus concentrations increased dramatically. The high inorganic N:P ratios obtained during late spring appear to be relatively meaningless in terms of a limiting nutrient, as nitrogen is rapidly exhausted. The disappearance of inorganic nitrogen in June and relative scarcity through most of the summer seems to indicate relatively light nitrogen loading during this period from external sources. Two main internal sources of nitrogen can be identified from the observed patterns of occurrance and distribution: 1) release from the sediments during winter stagnation under anoxic conditions, and 2) release from littoral sediments during late summer due to invertebrate bio-activity, bacterial metabolism, and macrophyte senescence. The strong pulse of NH_3 observed at Enclosure 5 and station V in September both suggest the significance of the latter source to late summer algal production. External sources readily identified include groundwater, in which concentrations run up to at least 100 ug/l, and precipitation, which adds a considirable mass of nitrate at ice melt in the spring.

Effects of Boating on Dissolved Nutrients and Macrophyte Distribution

The effects of the operation of power boats in shallow water on dissolved nutrient concentrations were evaluated on July 1-2 by operating a 16 foot boat with a 40 hp outboard motor in two small areas 1 and 1.8 meters in depth. The boat was circled in a small area for about 5 minutes, then samples were collected from mid-water at 30 seconds and 5 minutes afterwards. Samples were also collected before operation began as controls.

Ammonia nitrogen, inorganic phosphorus, dissolved organic phosphorus, and total phosphorus were analysed. Ammonia decreased from 46 to 30 ug/l at 1 meter and increased from 25 to 41 ug/l at 1.8 meters. Inorganic phosphorus decreased by about 50 percent at 1 and 1.8 meters. Dissolved organic phosphorus decreased slightly at 1 meter and increased slightly (3ug/l) at 1.8 meters. Total phosphorus remained about the same or decreased slightly at both depths. Changes in phosphorus were insignificant. The observed changes in ammonia nitrogen under conditions of very high density boat traffic could cause minor increases in internal nutrient loading of nitrogen. However, considering the fact that the greatest boating activity occurs in midsummer, when nitrogen supplies in the water are at a minimum, and the observed natural regeneration of NH_3 nitrogen by benthic communities in Enclosures 5 and 6, it seems unlikely that boating at present or foreseeable levels can have a significant effect on chemical water quality or phytoplankton growth in Georgetown Lake.

Concern has been expressed that the operation of power boats in shallow water will cause a proliferation of macrophytic vegetation in the reservoir, or should a macrophyte control program be initiated, cause the respread of macrophytes into areas where control has been established. There can be no question that operation of propeller driven boats in areas heavily grown up with macrophytes causes the cutting and release of stems and leaves, which in some cases are capable of reestablishing themselves and forming new rooted plants. However, the vast amount of evidence observed in Georgetown Lake and in other lakes (Schulthorpe, 1967), is that natural breakage and release is more than adequate to accomplish the same effect in a closed system such as Georgetown. Should the case arise where a new and highly invasive species appeared in Georgetown Lake in a few isolated areas, it would be well to consider some limitations on the operation of power boats in specific areas where that species occurred. Under existing circumstances, where most of the basin is covered with macrophytic vegetation and all species are widely distributed, it does not appear that the limitation of power boat use for the purpose of weed control will serve any beneficial purpose. However, should intensive, large-scale in-lake management practices (such as mechanical harvesting) be implemented, further consideration should be given to the potential role of outboard boats in causing the spread of cut plant fragments.

SEDIMENT ACCUMULATION AND CHEMICAL RELATIONSHIPS

The location of sediment core sampling sites is shown in Fig D. The vertical profile of average sediment density is given in Table 23. The mean total depth of sediment cores obtained was 24 cm (range 10 -35 cm). Most cores showed a definite vertical physical stratification, or profile, within which could be distinguished features which defined the extent of deposited lake sediments. The presence of coarse gravel, the predominance of clay, and/or the absence of animal debris, such as snail shells, were taken as evidence that the origin of the material below the occurrence of such characteristics was not due to deposition of aquatic sediments. Based on these criteria, the average depth of aquatic sediment deposition was calculated as 20 cm (n = 20, range = 10-32 cm), or 7.8 inches. The deepest sediment deposits occurred in protected areas, such as Phillipsburg Bay, Stewart Mill Bay, upper Jericho Bay, and in deeper areas near the dam. The shallowest deposits occurred in areas exposed to maximum turbulence, such as Rainbow Point, the area off Highway 10A, and areas off Stewart Mill Bay. Intermediate sediment depths occurred in protected areas too deep for macrophyte growth, such as Red Bridge.

Table 23. Sediment mass-density, dry weight gm/cm^3.

Sediment Depth	N	Mean	Range
0-5 cm	5	0.42 g/cm^3	0.17-0.58
5-10 cm	5	0.74 g/cm^3	0.49-1.06
10+ cm	5	0.79 g/cm^3	0.59-0.91

Taking the approximate age of the reservoir to be 80 years (1901-1982), the average overall rate of deposition is about 0.25 cm (= 0.10 inches)/year, equivalent to about 1050 gms dry matter /m^2/year. The maximum observed rate was estimated to be about 0.40 cm (= 0.16 inches)/year, representing the deposition of approximately 1680 gms of dry matter per m^2 per year. The minimum rate calculated was about 0.13 cm (= 0.05 inches)/year. By comparison, Prentki (1979) calculated the rate of sediment deposition in Myriophyllum spicatum beds of Lake Wingra to be about 0.7 cm/year, representing the deposition of over 1600 grams dry weight per square meter per year of plant and animal detritus and mineral deposits. This is directly comparable to the value for deposition of dry matter in high rate deposition sites for Georgetown Lake, although the rate of vertical accretion is less in Georgetown, possibly due to a greater compaction of the surface sediments. Prentki also obtained similar values for the deposition of dry matter throughout the remainder of Lake Wingra, approximately 1200 gms dry weight/m^2 /year. Stefan and Hanson (1980) reported sediment accrual rates of 0.12 cm/yr in Hall Lake, Minnesota, as determined by ^{14}C dating, and Dunst (1980) reported sediment accrual rates in a small eutrophic lake in Wisconsin to be about 0.40 cm/year.

Based on the distribution of core depths obtained, sedimentation rates in deeper macrophyte beds are approximately equal to those in shallower areas, apparently due to export of sedimented organic detritus. Rich and Wetzel (1978) found a similar situation and postulated that wind-driven turbulence was responsible for redistribution of organic sediments.

Values of total sediment phosphorus for Georgetown Lake are compared to sediment phosphorus and other nutrient parameters for some other eutrophic lakes from which data are available in Table 24. The average total phosphorus concentration obtained in surficial sediments in 1981 was 571 ug/g, which is within the range obtained by Garrison (1976) for surface sediment material collected from five sites around the reservoir during 1973-74.

The mean total phosphorus concentration in surficial sediments from Georgetown Lake (calculated from data of Garrison, 1976) is 950 ug/g. In Garrison's data, variations in total sediment phosphorus appear to be randomly distributed on a seasonal basis. Sampling error is a likely cause of the lack of any consistent relationship between sediment phosphorus and dissolved/suspended phosphorus.

The average total phosphorus concentrations obtained in surficial sediment from Georgetown Lake (950 ug/g, 1974; 571 ug/g, 1981) is within the range of sediment total phosphorus concentrations from other shallow, eutrophic lakes (range 575-1231 ug/g) (Wildung and Schmidt, 1973). Sediments from Lake Mendota, which is somewhat deeper than other lakes considered, contained 1950 ug P/g dry sediment, and other deeper eutrophic lakes have had values reported of over 5000 ug P/g (Stauffer, 1981).

Sediment phosphorus in Shagawa Lake showed no statistically significant spatial variation, indicating some normalizing processes in sediment phosphorus distribution (Wildung and Schmidt, 1973). This is in spite of a point source effluent from Ely, Minnesota via

Table 24. Comparisons of sediment chemistry for Georgetown and other eutrophic lakes.

Lake		$\%C_T$	C/P	N_T	C/N	P_T	N/P	P_I	P_I/P_T
Georgetown[1]									
1974	St. 1	12.6	412	0.90	16.3	789	25.3	522	66%
	St. 2	16.6	373	1.35	14.4	1150	26.0	731	64%
	St. 3	15.0	413	1.21	14.5	939	28.5	555	59%
	St. 4	27.6	599	2.12	15.2	1190	39.4	646	54%
	St. 5	9.1	346	0.75	11.1	680	24.4	414	61%
Average		16.1	438	1.27	14.9	950	29.6	571	60%
Georgetown 1981	Average					571		363	
Shagawa Lake[3]		12.2	256	1.20	11.9	1231	21.6	691	57%
Upper Klamath Lake[3]	St. 1	7.4	185	0.88	9.8	1033	18.9	574	56%
	St. 2	6.6	271	1.01	7.6	629	35.6	295	47%
	St. 3	6.5	254	0.95	8.0	662	31.8	349	53%
Average						775	28.9		
Erie[3] (grand mean)						865		651	75
Agency[3] "						575		328	57
Diamond[3] "						659		252	38
Mendota[2]						1950			

Data from Garrison (1976)[1], Stauffer (1981)[2], Wildung and Schmidt (1973)[3]. Total carbon (C_T) and total nitrogen (N_T) are expressed as percent dry weight of sediment. Phosphorus (P) is expressed as ug/g dry weight of sediment. P_T = Total phosphorus; P_I = inorganic phosphorus.

the Burntside River. Highest total phosphorus values were obtained in deep "holes" near the sewage outfall, reflecting the possible influence of turbulence and sedimentation in influencing the redistribution of phosphorus. A trend of increasing phosphorus with increasing water depth in upper Klamath Lake was explained through agricultural runoff, although total loading from cultural sources was estimated at only 25 percent. Upper Klamath Lake was described as a shallow, naturally eutrophic lake, subject to periodic dense algal blooms, which in some cases reduced Secchi disc depths to <0.5 M. Phosphorus leachates from Upper Klamath Lake were fully active in promoting algal growth when compared to inorganic phosphorus (Wildung and Schmidt, 1973).

Total phosphorus concentrations in sediment cores from Georgetown Lake showed a sharp decrease with increasing depth (Table 25).

Table 25. Vertical distribution of total phosphorus in sediment cores from Georgetown Lake. Sampling locations shown in Figure 2.

Site	Phillipsburg Bay	Jericho Bay	Red Bridge	Pump House
Depth (cm)	Concentration (ug/g dry sediment)			
0	670	925	615	335
5	560	700	475	285
10	420	440	328	232
15	290	350	230	275
20	200	329	180	265
25		370	230	205
30		260		160
Depth (cm)	Mass density (ug P/cm^3 sediment)			
0	370	400	230	135
5	360	365	230	150
10	325	320	230	175
15	223	265	170	215
20	170	255	140	215
25		290	139	165
30		220		125

However, the lower density of surface sediment alters the apparent concentration gradient. "Mass-density" profiles for phosphorus shown in Table 41are very similar to those obtained for unfertilized Montana rangeland (Table 26) by Wight and Black (1977).

Concentrations of phosphorus (ug/gm dry sediment) for Georgetown Lake sediments and surface layers of sedimentary rangeland soils are also similar (950 and 775 ug/gm respectively).

Table 26. Concentrations of total phosphorus (ug/g soil dry weight) in unfertilized sedimentary Montana rangeland soil (from Wight and Black, 1977).

Depth in Soil Profile (cm)	P Concentration ug/g dry weight
0-3	780
5-8	750
9-15	700
16-21	560
23-30	500

The phosphorus profile for unfertilized Montana range soil indicates that natural biogeochemical processes are sufficient to create a substantial phosphorus gradient in terrestrial soils. There are several natural processes which would tend to create the observed gradients in Georgetown Lake sediments. It has been shown that rooted aquatic vascular plants are capable of extracting most of their required phosphorus from sediments at depths up to 20 cm (Carignan, 1982; Barko, et al, 1982). The uptake of phosphorus from deeper sediments and subsequent redeposition in autochthonous detritus, which has been shown to be accumulating at a slow rate in Georgetown Lake (present data and Garrison, 1976), would tend to cause a gradual depletion of phosphorus in deeper sediments, which is indicated by the apparent low phosphorus concentrations at sediment depths of 20-30 cm, and enrichment at the surface. The average phosphorus concentration in surface sediments, which is 0.05-0.1%, is consistent with the average phosphorus content of aquatic macrophytes (0.25-0.3%), when other components of autochthonous sediments, primarily silicates, carbonates, and organic detritus from plankton, are considered. Mobilization of deeper sedimentary phosphorus supplies by roots of aquatic vascular plants, which were observed in the deepest layers of sediment cores from Georgetown Lake and which other researchers have observed to depths of 50 cm and more (Reimold, 1974), and subsequent deposition on the surface provides a mechanism for concentration near the surface layers.

Several investigators have reported an increase of phosphorus in aquatic sediments due to increased external phosphorus loading (Wagner, 1972; Golterman 1980; Larsen and Mercier, 1976). Golterman (1980) has described a relationship between external loading and phosphorus sedimentation rates as follows:

$$A = k\ (P_w)^v, \text{ where}$$

A = P concentration in sediment
P_w = P concentration in lake water
k = approximately 0.62, a constant
v = approximately 0.34, a constant

Combining this equation with a form of the phosphorus balance equation, given by Golterman (1980) as

$$P_{in} = P_{out} + P_{sed} + dP_w$$

P_{in} = P input
P_{out} = P output
P_{sed} = P sedimented out in receiving water
dP_w = change in P concentration in receiving water

the resulting equation is obtained:

$$P_{in} = P_{out} + A\ K\ (P)^v + dP_w\ z \quad (z = \text{mean depth})$$

The values for k and v were calculated by Golterman from experimental data on natural sediments. This relationship predicts that phosphorus content in sediment will approximately double as phosphorus concentrations in the overlying water increase by a factor of 10 in the range of 1-500 ug P/l. Data of Wagner (1972), which showed a 2.2-fold increase of sediment phosphorus content in response to a 10-fold increase in phosphorus concentrations in the overlying water, verified the relative accuracy of the predicted response.

Using experimental values obtained for the vertical distribution of phosphorus and rate of sediment deposition in sediments of Georgetown Lake, Golterman's equation predicts that the concentration of phosphorus in Georgetown Lake water would be increasing at a rate of about 10-fold every 40 years to cause the observed four-fold increase in phosphorus near the sediment surface. This requires the assumptions of a background phosphorus concentration of 225-250 ug P/gm dry sediment at a depth of 20 cm below the sediment surface, a sediment phosphorus concentration of 950 ug/gm dry sediment at the surface (approximated by value obtained by Garrison, 1976), and an average annual sedimentation rate of 0.25 cm/year over the life of the reservoir (approximately 80 years).

Total phosphorus concentrations in the reservoir, inflowing streams, and outflows do not support the hypothesis that the increase in sediment phosphorus content nearer the sediment surface is due to increases in phosphorus sedimentation from external sources. There does not appear to be a trend toward increasing external phosphorus loading, or an increase in net phosphorus throughput (see Nutrient

Budgets). Total phosphorus concentrations in 1973-75 (Knight, et at, 1975) and 1981 indicate a relatively stable or decreasing average phosphorus concentration in the reservoir during summer.

By integrating the phosphorus mass density for the top 20 cm of sediment, a rough approximation of the total phosphorus supply in the lake sediments can be estimated, although it must be realized that the entire mass does not represent phosphorus which is readily exchangeable with water or available to rooted aquatic plants for growth (Stauffer, 1981). The mean phosphorus mass per centimeter square of sediment surface was calculated at 5120 ug, which is equal to 51.2 g per square meter and 619,500 kg for the entire reservoir. At the estimated loss rate of 35 mg $P/m^2/yr$ (see Nutrient Budget), the sediment supply in the top 20 cm of sediment and soil represents approximately 1500 times this value. Apparently the phosphorus mass in the sediment is acting as a stabilizing buffer in the aquatic system, tending to hold dissolved phosphorus near the same levels from year to year in spite of a negative phosphorus budget (see Nutrient Budgets). Both the estimated total mass present and loss rates should be considered minimum values, as the data from which they were derived were the most conservative available.

Yoshida (1981) presented evidence based on laboratory experiments and theoretical considerations that phosphorus release from sediments asymptotically approached a maximum value at a sediment depth of about 30 cm. His release rates were about 75% of maximum at a total sediment depth of 20 cm. Based on this evidence, internal phosphorus loading in Georgetown Lake (due to direct exchange between water and sediment) should be at or approaching maximum values and would not be expected to increase without additional external inputs.

Garrison (1976) estimated atomic N:P ratios in the sediment to be 31:1. If this ratio holds throughout the sediment profile, the total nitrogen mass present in the shallow sediments is estimated at 1.37 x 10^6 kg. Nitrogen in aquatic systems is much more labile than phosphorus (Brezonik, 1972), due to the various processes of transformation. Nitrogen:phosphorus ratios in the water might be expected to fluctuate seasonally and annually according the specific local or environmental conditions which favored one process or the other. It does not seem that N:P ratios in Georgetown Lake sediments provide an accurate indication of relative availability of nutrients to the biosphere, due to the interference of specific chemical processes which affect chemical species present in the free water. N:P ratios in nutrient budgets and sediments predict that phosphorus should be in short supply relative to nitrogen, yet N:P ratios during part of the growing season (late June-early August) and algal bioassay (EPA, 1976) show nitrogen to be apparently limiting, although removal of the nitrogen limitation by addition of inorganic nitrogen resulted in phosphorus limitation at a slightly higher standing crop. Late summer increases of dissolved ammonia in Enclosure 5 and at Station V indicate the potential for internal loading of inorganic nitrogen and the significance of internal nutrient sources in stimulating late-summer algal growth.

NUTRIENT BUDGETS

Nutrient budgets for nitrogen and phosphorus were calculated for 17 June 1981-31 May 1982. Inputs and outputs from surface streams were based on the product of gaged stream discharge and analytical concentrations of all forms of the nutrient under consideration for a given unit of time. In cases of missing data on nutrient concentrations, values were used from U. S. Forest Service data or data obtained under similar flow conditions. Concentrations of total nitrogen and phosphorus in surface streams are given in Table 27.

Analyses of groundwater samples from shoreline seeps and submerged springs indicated that the chemical constitution of Stewart Mill Creek approximates that of other groundwater sources in the reservoir (Knight, 1980; Garrett, 1983). Therefore, flow-weighted averages of total nitrogen and phosphorus in Stewart Mill Creek were used to approximate groundwater inputs.

Non-point contributions were based on nutrient export and runoff coefficients given in Reckhow, et al, (1980), and McElroy, et al, (1976), for land use and land cover types similar to those present in the drainage. Only direct surface runoff was considered in the non-point estimate, as contributions from septic tanks, groundwater, and atmospheric sources were included separately. It was assumed that direct surface runoff was contributed from a radius 0.5 km around the reservoir, the area of which is approximately 1,360 ha.

From data given in Table Ala of Reckhow, et al (1980) a

Table 27. Monthly averages of nitrate and ammonia nitrogen concentrations in surface streams flowing into and out of Georgetown Lake. Concentrations in ug/l.

	NO_3			NH_3		
	NFFC	SMC	FCO	NFFC	SMC	FCO
Jul 73	3	60	3	1	1	17
Aug 73	6	72	20	3	2	3
Sep 73	8	62	26	0	0	6
Dec 73	6	70	7	1	2	46
Jan 74	15	34	0	0	0	75
Feb 74	20	58	8	7	4	300
Apr 74	20	79	20			
Jun 74	4	28	3	1	2	1
Jul 74	3	60	14	8	7	12
Aug 74	5	72	12	11	8	11
Sep 74	5	69	3	12	8	12
Nov 74	6	55	7	6	6	7
Dec 74	0	53	0	8	8	28
Jan 75	16	50	32	5	5	46
Feb 75	21	66	7	8	8	277
Mar 75	16	54	10	6	4	159
Apr 75	31	54	0	10	6	162
May 75	0	35	9	6	3	145
Jun 75	1	54	14			
Jun 81	0	42	0	6	4	4
Jul 81	0	40	1	4	4	1
Aug 81	0	52	0	8	4	3
Sep 81	0	51	2	6	13	12
Oct 81	0	58	0	0	0	0
Nov 81	0	64	0	0	0	8
Jan 82	12	78	5	4	0	106
Feb 82	12	73	5	0	0	139
Mar 82	13	75	12	23	11	124
Apr 82	21	99	27	0	0	68
May 82	13	73	13	0	18	156

linear regression for phosphorus export from western coniferous forest was calculated, resulting in the following equation:

$$P \text{ (export) kg/ha/yr} = 0.3699 \ln \text{runoff (cm)} - 0.9035.$$
$$r = 0.8997 \quad n = 4$$

Due to the small number of data points, it is difficult to attach statistical significance to this equation. However, from data of Frederickson (1979), with a runoff of 76 cm/yr a phosphorus export of 0.698 kg/ha/yr was calculated, which agrees well with his experimental value of 0.680 kg/ha/yr. Precipitation at Georgetown Lake is approximately 50 cm/yr, of which 30% was assumed to run off (Reckhow, et al, 1980), giving a total runoff of 15 cm/unit area. Substituting this into the regression equation, a total phosphorus yield of approximately 0.1 kg/ha/yr was obtained. Less than 10% of the total runoff occurs as surface runoff (McElroy, et al, 1976). However, for study purposes, a conservative value of 25% was assumed. Therefore, the export of phosphorus in direct surface runoff was estimated as 0.25 x 0.1 kg/ha/yr = 0.025 kg/ha/yr. This value was also used for native grasslands and residential areas, most of which have been left in a natural state. Data from Reckhow, et al, (1980) indicate that this is a conservative estimate for grasslands, which have low ratios of runoff:precipitation and correspondingly low phosphorus yields. Thus the total non-point phosphorus load was calculated as 0.025 kg P/ha/yr x 1360 ha = 34 kg P/yr.

A similar calculation for total nitrogen export gave the equation

$$N \text{ (export) kg/ha/yr} = 3.404 \ln \text{runoff (cm)} - 4.7748$$
$$r = .879 \quad n = 4$$

Substituting a value of 15 cm total runoff, total nitrogen export was estimated at 4.4 kg/ha/yr, and that due to surface runoff at 1.1 kg/ha/yr. This gives a calculated non-point nitrogen load of 1.1 x 1,360 = 1496 kg N/yr.

Inputs from septic tanks were based on export coefficients given by EPA (1975). The values given for annual export coefficients for nitrogen and phosphorus (0.1134 kg P/capita/yr and 4.263 kg N/capita/yr) were modified by residential use data obtained during the septic leachate survey accomplished in 1981. Results of the residential survey indicated that the average residence was used at a rate equivalent to 0.7 per capita years, i. e., occupancy by one person for 0.7 years/calendar year. Thus the average load per residence was estimated at 0.08 kg P and 2.98 kg N per year x 125 near-shore residences equals 10 kg P and 373 kg N/year.

Loading due to campground facilities was calculated on the same basis. With a total capacity of approximately 235 spaces, and assuming 70% occupancy by an average of 3 persons for 4 months a year, the potential loadings were calculated as 18.5 kg P and 427 kg N per year. Commercial facilities (restaurants, bars) were assumed to contribute approximately the same as campgrounds (18.5 kg P and 427 kg N per year).

Fish harvest data were provided by Jim Vashro, Montana Department of Fish, Wildlife, and Parks fisheries biologist. Nitrogen and phosphorus concentrations in fish flesh were taken from Neel, et al, (1973) as 2.4% N and 0.50% P on a wet weight basis. Fish harvest is composed primarily of Kokanee salmon, which reproduce naturally in the reservoir, and rainbow trout, of which about 250,000-350,000 are planted annually as fry or fingerlings. The biomass and phosphorus content of the planted fish is thus negligible in terms of N and P input. Approximately 125,000 rainbow trout (average weight 0.27 kg) and 175,000 Kokanee (ave. weight 0.16 kg) are harvested annually, representing a net output of approximately 310 kg P and 1550 kg N per year. This constitutes 25 % and 12% of the phosphorus and nitrogen outputs, respectively.

Comparisons of the phosphorus and nitrogen budgets calculated for 1981-82 and previous nutrient budgets (Knight, et al, 1975; EPA, 1976) are shown in Tables 28 and 29, respectively. The budget of Knight, et al, (1975), has been recalculated to include estimates of atmospheric and non-point inputs (septic tanks, direct runoff, groundwater). The EPA budgets lump hydrologic sources other than the North Fork of Flint Creek and direct surface runoff into non-point sources.

In comparing phosphorus budgets, the most significant aspect is that all result in a negative phosphorus loading relationship, which indicates that the phosphorus status of Georgetown Lake is relatively stable and more than likely the reservoir is losing phosphorus annually. Also significant is the small contribution calculated for septic tanks, which have been repeatedly implicated in cases of cultural eutrophication, but which recent work (EPA and Wapora, Inc., 1981) has shown to be much less significant than previously thought. Considering the phosphorus mass available in the sediment and the potential for internal loading to the biological community via

Table 28. Comparison of phosphorus budgets for Georgetown Lake. Inputs and outputs in Kilograms per year. Net balance in kilograms/lake.

INPUTS	Knight, et al, 1974-75	EPA 1975	Garrett 1981-82
NFFC	262	95	175
Stewart Mill Ck	198	(*1)	101
Groundwater	200(*3)	200-380	200
Non-point	34(*3)	435	34
Hardtla Creek	103	(*1)	30
Septic tanks	47(*3)	55	47
Atmospheric	218(*3)	195	224
Total	1062	980-1160	811
OUTPUTS			
Fish Yield	250-350	250-350	250-350
Flint Creek	1060	730	920
Anaconda aqueduct	621	500	-0-(*2)
Total	1931- 2031	1480- 1580	1170- 1270
NET BALANCE			
Kg/lake/yr	-869>X>-969	-320>X>-600	-359>X>-459
mg/m^2/yr	-72>X>-80	-37>X>-76	-30>X>-38

*1 Included in non-point sources.
*2 Personal communication, Ron Eccleston, Anaconda Company
*3 Calculated from 1981-1982 data.

macrophytes and detritus cycling, it is unlikely that foreseeable increases in phosphorus loading from cultural sources will cause significant increases in total primary productivity.

Differences in nitrogen budgets are larger, for which there may be several reasons. The high input estimate for nitrogen by the EPA is due to their non-point source component (45.4%), which, considering the evidence of nitrogen/phosphorus ratios in water and sediment, would appear to be an overestimate. It is noteworthy that the atmospheric component is the next largest source of nitrogen, and is not subject to management. EPA estimates of inputs of nitrogen and phosphorus are at a ratio of approximately 70:1, while N:P ratios in the water range from 10:1 to a maximum of about 50:1, that observed during late winter (Knight, 1980). N:P ratios in the sediment (31:1, Garrison, 1976) also run much lower than one would expect if such a high input ratio were real.

The high nitrogen output estimated by EPA may be the result of a sampling artifact. It was found during 1981 that samples from the dam outflow collected several hundred yards below its discharge from the power station results in high values of nitrate, probably from groundwater contamination. Increases from 50-75 ug/l were observed on several occasions. Additionally, total nitrogen in reservoir water was shown to have been considerably higher in 1974-1976, possibly due to nitrogen fixation by phytoplankton or enhanced release of ammonia and organic nitrogen from benthic sediments. It appears that the nitrogen budget is much less stable than phosphorus and may fluctuate considerably from year to year.

The average nitrogen content of macrophytic vegetation in Georgetown Lake is around 2.8%. Assuming a standing crop of 250 g dry weight/m^2 over 60 % of the reservoir surface results in approximately 50,000 kg of nitrogen being tied up in macrophytic vegetation. This amounts to approximately twice the estimated annual nitrogen input for 1981-1982, and reflects the importance of internal nutrient supplies to aquatic plant growth. The calculation is hypothetical, but represents easily obtainable conditions in the reservoir, and corresponds with the very low dissolved inorganic nitrogen concentrations found during the summer of 1981 and 1982.

TABLE 29. Comparison of nitrogen budgets for Georgetown Lake. Units for input and output and net balance are kg/lake/year.

INPUTS	KNIGHT, *et al*, 1974-75	EPA/NES 1975-76	GARRETT, 1981-82
NFFC	2330	3920	2558
SMC	2130	(*1)	1804
GROUNDWATER	3450(*2)	(*1)	3450
NON-POINT	1496(*2)	17960	1496
HARDTLA CK	1730	(*1)	350
SEPTIC SYSTEMS	1227(*2)	2125	1227
ATMOSPHERIC	12090(*2)	12090	13888
TOTAL	24453	36095	24773
OUTPUTS			
FISH YIELD	1550	1550	1550
FLINT CK	11200	22290	11426
AQUEDUCT	6650	15255	-0-(*3)
TOTAL	19400	39095	12976
BALANCE			
Kg/lake/yr	5053	-3000	11797
gm/m^2/yr	0.42	-0.25	0.97

*1 Included in nonpoint estimate.
*2 Calculated from 1981-1982 data.
*3 Personal communication, Ron Eccleston, Anaconda Company.

Considering the relative magnitude of cultural sources, it does not appear that any significant changes in the current nitrogen balance can be effected by external management. Major changes in land use patterns, such as a shift to agricultural uses of the basin, or introduction of a point source effluent of considerable size would be required to significantly alter the nitrogen budget.

According to the Vollenweider loading model (Reckhow, 1979), Georgetown Lake is oligotrophic based on phosphorus loading, and in the upper end of the safe range relative to nitrogen loading. A nitrogen loading rate of about 1 gm/m^2/year was calculated for 1981-82, which is right at the limit of "safe" loading, but well below the criteria of 2 g/m^2/yr for "dangerous" loading (definitions by Reckhow, 1979). Considering the variability in nitrogen output, demonstrated by the estimate for 1974-75 compared to 1981-1982, it appears that net nitrogen loading can vary considerably from year to year, and 1981-82 may represent a maximum loading situation.

The average concentrations of inorganic and total phosphorus in the discharge were considerably lower in 1981-1982 than in 1973-1974 (20 and 31 ug/l, respectively). A possible cause is found in the relationship between reservoir elevation, dissolved oxygen and phosphorus in the discharge, which is withdrawn approximately 1.5 m above the sediment, during the winter. Representative elevations, dates, and maximum concentrations of inorganic and total phosphorus at Station I and in the outflow are given in Table 30. Linear correlation coefficients for surface elevation against phosphorus in the outflow, maximum phosphorus concentration near the bottom at station I are highly significant (Table 31). The relationship apears to be mediated by dissolved oxygen concentrations, as comparison of dissolved oxygen data of Knight (1980) indicate that deficits were much more severe in 1973-74 than in 1981-82.

Other factors may affect phosphorus concentrations in the outflow. Snow cover enhances the development of oxygen deficit, thus

Table 30. Relationship between water surface elevation and phosphorus (ug/l at deepest sampling depth) at station I and the outflow during winter stagnation.

Date	Elev	site	Inorg-P	Total-P
18 Feb 74	25.6	I	54	54
		Outflow	62	72
25 Apr 74	25.2	I	114	134
		Outflow	72	100
23 Apr 75	26.4	I	57	107
		Outflow	51	72
25 Mar 82	28.4	I	18	39
		Outflow	3	25
1 May 82	28.5	I	13	30
		Outflow	2	20

Table 31. Correlation coefficients for inorganic and total phosphorus at Station I and the outflow against water level during winter stagnation of Georgetown Lake.

	Inorg P	Total P
Station I	-0.894*	-0.767
Outflow	-0.767	-0.975

N = 5; P(.05) = 0.811; P(.02) = 0.882

heavy snow cover will encourage phosphorus release. Total phosphorus release from the sediment is a time-sequenced event, thus one would expect greater phosphorus concentrations later in winter stagnation, but recent data do not indicate that this is necessarily the case, depending the further development of the dissolved oxygen deficit. Mathias and Barica (1979) found mean depth to be highly significant in influencing the total oxygen deficit. It appears that phosphorus in Georgetown Lake may be amenable to manipulation by water level control within the limits necessary for fish survival.

Nitrogen does not appear to show the same relationship. Inorganic nitrogen concentrations were higher near the sediment-water interface in 1981-82, possibly because the sampling device allowed sampling closer to the substrate.

MACROPHYTE COMMUNITIES

The most significant biological feature of Georgetown Lake is the benthic plant community, which appears to be the driving force of lake metabolism and strongly influences chemical cycles of carbon, nitrogen and phosphorus. Aerial color infra-red photography obtained in 1975, 1981, and 1982 indicates that benthic macrophyte coverage is esentially complete in terms of presence, to a minimum depth contour of 6409.5 on the Anaconda gage (maximum surface elev. 6429.5), representing a depth at full pool of about 6 meters. The shallow mean depth of 4.84 meters confirms that macrophyte communities are present over 75-80 % of the total surface area, as the euphotic zone is typically 5 meters or more in depth during the growing season.

A list of the major taxa identified is given in Table 32. Due to the concern regarding the possible presence of *Myriophyllum spicatum*, specimens were collected in 1981 from several stands in the reservoir, mounted, and sent to Dr. Susan Aiken, University of Minnesota Herbarium, for verification. All specimens were verified as *Myriophyllum exalbescens*. Several characteristic plant communities were identified, although many species are widely distributed and occur across a considerable depth range. The border of the reservoir to a depth of about 0.75 m, which spans the normal zone of fluctuation in water level, is characterized by the presence of *Chara* sp., occurring in sparse to dense mats with standing

Table 32. Submerged and floating-leaved aquatic vascular plants identified in Georgetown Lake. Nomenclature according to Hitchcock and Cronquist (1973) and Muenscher (1944).

ALISMATACEAE
- *Alisma plantago-aquatica* L.

POTAMOGETONACEAE
- *Potamogeton alpinus* Balbis
  - *friesii* Rupr.
  - *gramineus* L.
  - *pectinatus* L.
  - *praelongus* Wulf.
  - *pusillus* L.
  - *richardsonii* (Bennett) Rydb.
  - *vaginatus* Turcz.
  - *zosteriformis* Fern.

SPARGANIACEAE
- *Sparganium eurycarpium* Engelm.

HYDROCHARITACEAE
- *Anacharis canadensis* (Michx.) Planchon.

LEMNACEAE
- *Lemna trisulca* L.

POLYGONACEAE
- *Polygonum amphibium* L.

CERATOPHYLLACEAE
- *Ceratophyllum demersum* L.

RANUNCULACEAE
- *Ranunculus aquatilis* L.

HALORAGACEAE
- *Myriophyllum exalbescens* Fern.

LENTIBULARIACEAE
- *Utricularia vulgaris* L.

ISOETACEAE
- *Isoetes howellii* Engelm.

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crops of up to 250 g dry wt/m^2. *Polygonum amphibium* also occurs in several areas within this depth zone, particularly around the mouth of Stewart Mill Bay, although it is scattered around much of the protected shoreline areas. It does not occur along windy shorelines which are exposed to much wave action, such as along Highway 10A.

Depth contours from 1-2 meters include communities dominated by *Myriophyllum exalbescens*, *Elodea canadensis*, and *Potamogeton richardsonii*, with a generally continuous understory of *Chara* sp. These three vascular plants are a dominant feature of the benthic plant community, occurring at depths up to 4 meters in many areas of the reservoir, usually accompanied by *Chara* as an understory. They are major primary producers in the reservoir, obtaining high standing crops over a wide depth range. Stands of *Potemogeton pectinatus* and *Potamogeton freiisi* occur around the 1-1.5 m contour and appear to be temporary features, depending on annual hydrologic and meteorologic conditions.

The most extensive plant community in the reservoir, in terms of area, is characterized by *Potamogeton praelongus*, which grows in clumps which reach the surface in midsummer, and produce aerial flowering spikes, interspersed with "meadows" of *Chara*, which also are colonized by *Elodea*, *Myriophyllum*, and *P. richardsonii*. The basic association occurs at depths ranging from 3.5 to 6 meters.

Potamogeton zosteriformis, a species common to high conductivity waters in eastern Montana (Wright and Booth, 1959), was present in high densities in 1973-76 along the shoreline bordering Highway 10A north of the inlet of the North Fork (Garrett, unpublished data), but was almost non-existent in 1981-82, having been replaced by P. praelongus in that area. Ranunculus aquatilis occurs at depths of 1-1.5 meters, and in some areas, notably around the mouth of Stewart Mill Bay and on the south shore of Jericho Bay, reaches densities sufficient to constitute a nuisance to boaters. Ceratophyllum demersum, although present in 1973-76, was not at any time abundant relative to the dominant species. This is not unexpected, as the species does not have a functional root system, as do Elodea, Myriophyllum, and other common species, and must obtain its mineral nutrition from dissolved nutrients in the water, sediment sources being relatively unavailable (Schulthorpe, 1967).

Other species present are relatively minor, do not contribute significantly to primary productivity, and do not constitute a nuisance to boaters or fishermen.

Aerial photography obtained in August of 1975, 1981, and 1982, revealed significant changes in the distribution and abundance of P. praelongus (Figs. M-P). Three areas, each covering approximately 4-7 Ha (9-18 acres) with overlapping imagery available were selected for analysis of canopy coverage. Each area represents a different level of colonization. All are approximately 4.5-5.5 m deep. P. praelongus (big-leaf pondweed) is a perennial (Schulthorpe, 1967), and clumps probably represent a few plants,

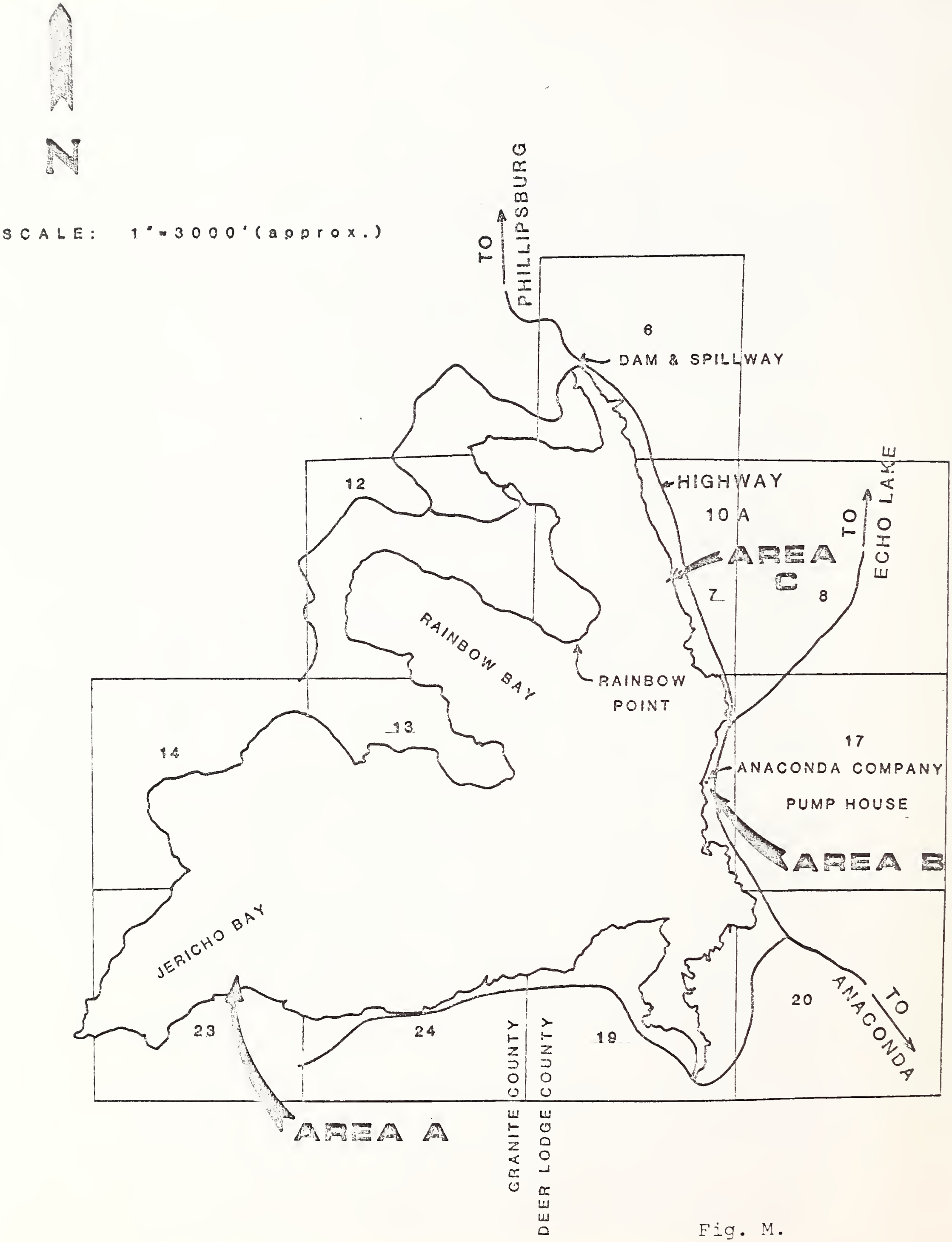


Fig. M.

LOCATION MAP FOR
STUDY AREAS A,B & C

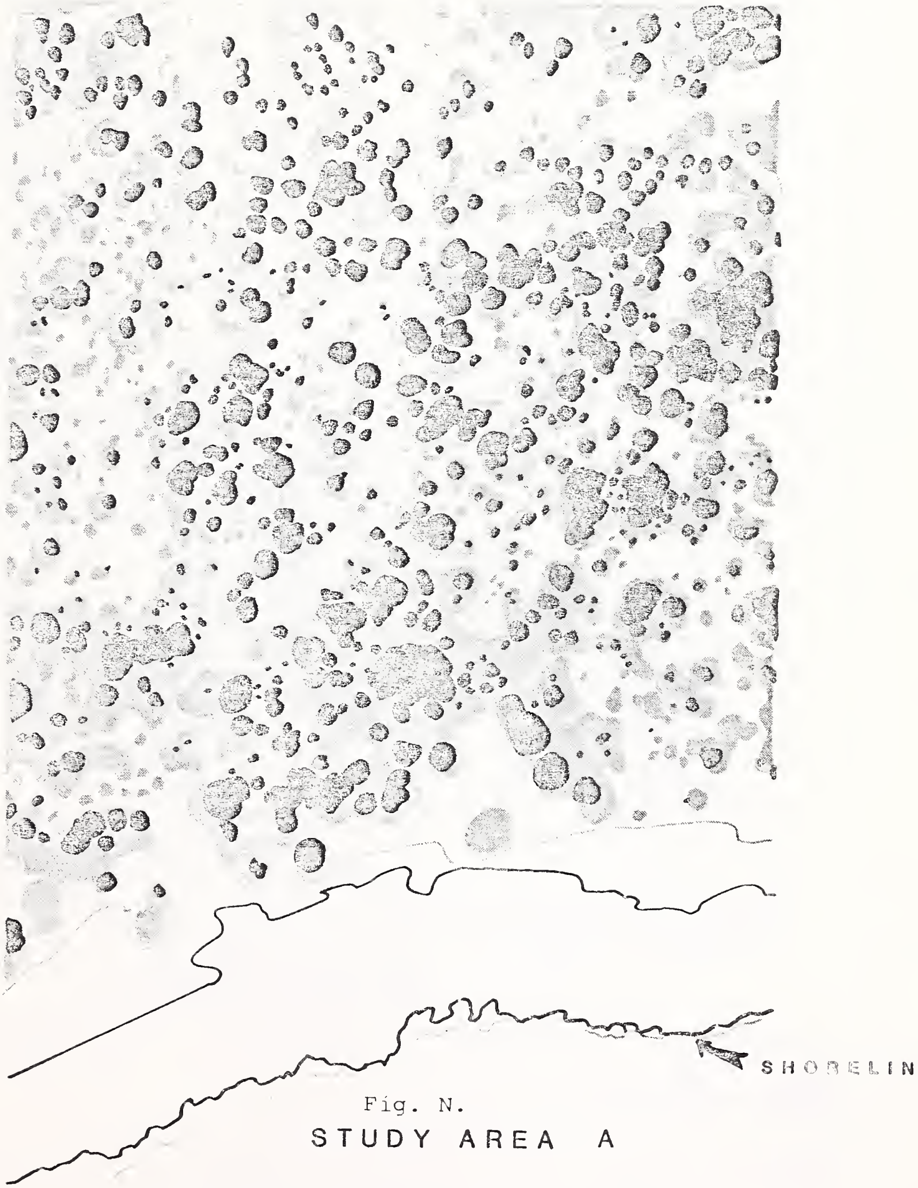
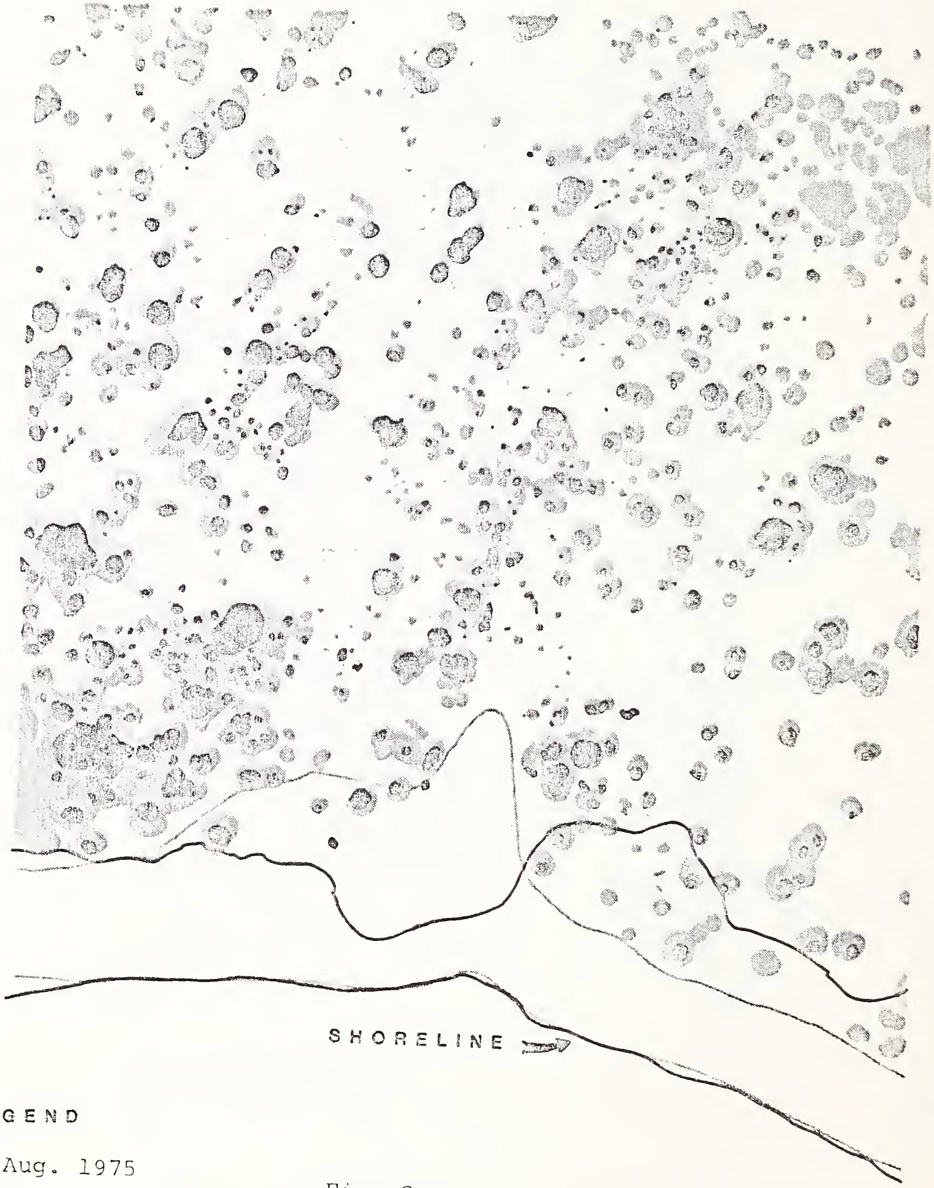


Fig. N.
STUDY AREA A

CHANGES IN SURFACE AREA OF BIG-LEAF PONDWEED (Potamogeton praelongus) from 1975 to 1981.

LEGEND
Aug. 1975 ▓
Aug. 1981 ░



LEGEND

▨ Aug. 1975

▨ Aug. 1981

Fig. O.

STUDY AREA B

CHANGES IN SURFACE AREA OF BIG-LEAF ONDWEED (*Potamogeton prealongus*) from 1975 to 1981

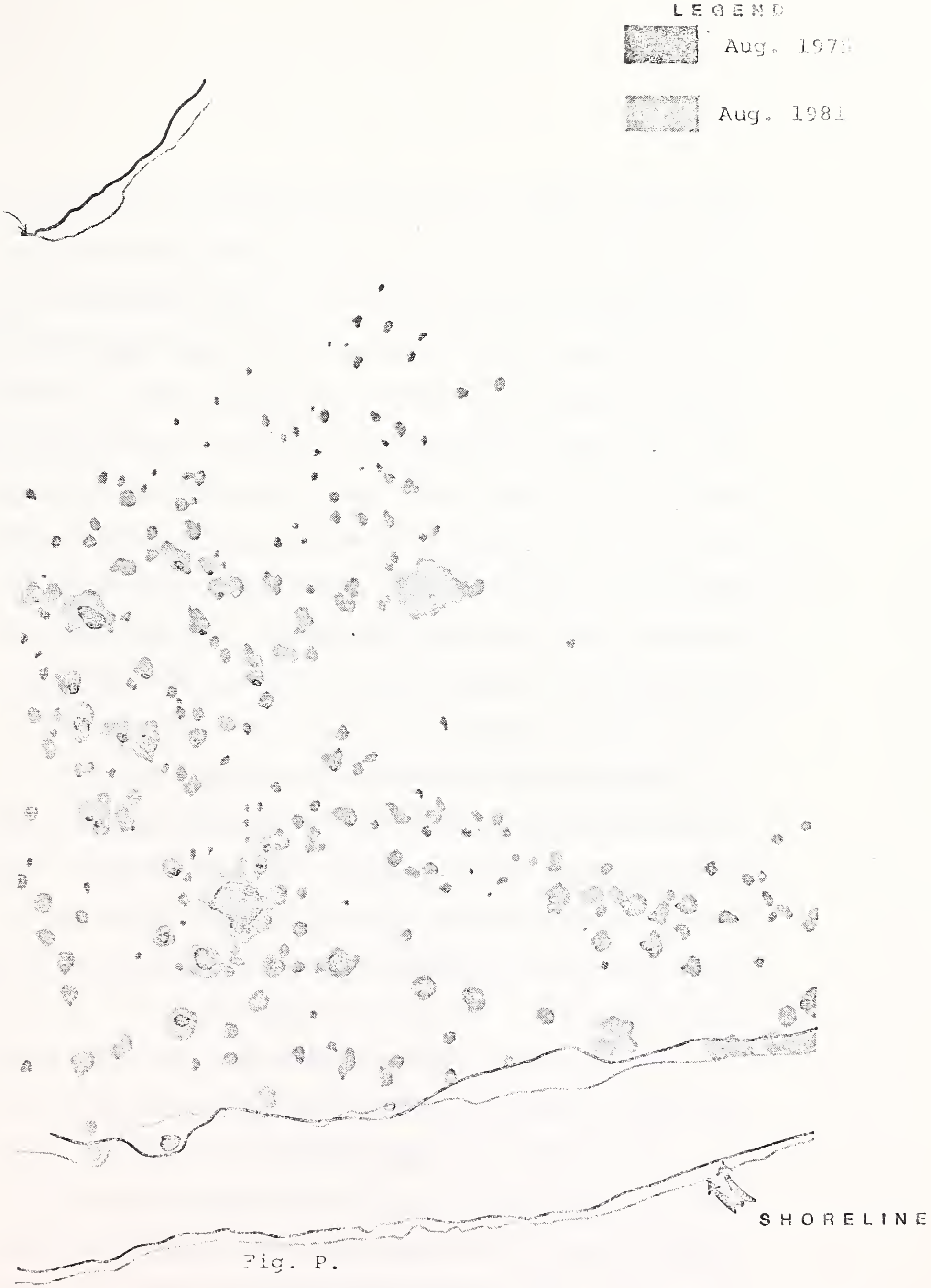


Fig. P.

STUDY AREA C

CHANGES IN SURFACE AREA OF BIG-LEAF PONDWEED (*Potamogeton praelongus*) from 1975 to 1981.

each with many stems interconnected by rhizomes. Individual clumps are recognizeable over all three years' photography, and in some cases it can be determined that several clumps increased in size to form a continuous stand. Observations with SCUBA showed that canopy coverage within a clump is 100 %, and that the stands are relatively pure, with little or no understory of any kind. Accumulations of detritus on the bottom form a loose layer of particulate organic matter, but accumulations of sedimentary detrital material were in general slight, with firm clay, silt or gravel often being encountered within 8-10 cm of the surface. Stem density was estimated in 1975 as approximately 20-30 stems/m^2, determined in several different stands.

Canopy coverage increased at sites A and B by 100 %, i. e., the extent of areal coverage (which in this case would also equal basal area of the stand) increased twofold. Total percent surface coverage in 1981 for site A was 62 %, at site B, 27 %. At site C, canopy coverage increased by 700 %, but the percent total coverage was less than 5%.

Photography of the same areas in 1982 showed no significant discernable changes in the canopy coverage of _P. praelongus_. It does not appear that the rapid increase of this species is a short-term event, but may continue under present reservoir management practices until all areas of the reservoir above the 6 m contour (6409.5 gage height) are colonized to some extent. Marked increases in this plant were also observed in the Phillipsberg Bay area, the stands there being very vigorous, with standing crops greater than those observed in other areas.

Distribution of other species was not evaluated by use of aerial photography, other than to determine the presence of plant canopy, which was relatively continuous in all areas of the reservoir between the 1 meter to 5 m contours, the latter representing the limit of image differentiation, using color and texture as recognition criteria. Exceptions occurred along the east shore between the pumphouse and the North Fork inlet, which is very windy and exposed to the full reach of wave action. In such areas wave turbulence has often been found to limit colonization by rooted aquatic plants (Spence and Jupp, 1971).

Standing crops were estimated for several areas in the reservoir in 1981-82 by harvesting 0.5 m quadrats with the aid of SCUBA. Underground parts were not included. Biomass development, and presumeably primary production, of macrophytes appears to vary considerably from year to year. In 1981, biomass accrual was 2-3 times greater in some stands than in other years observed (Garrett, unpublished data). On 18 August, 1981, average standing crop of Elodea canadensis near station V was 735 g/m^2 dry weight, and a mixed stand of P. richardsonii-Elodea-Chara obtained an average standing crop of 396 g/m^2. On the same date, a standing crop of 320 g/m^2 dry weight was obtained for P. praelongus in Philipsburg Bay, which is greater than any other standing crop observed for that species, maxima in other years being about

250 g/m^2. In comparison, maximum standing crops of Elodea in 1974-76 were 350-425 g/m^2, and maximum standing crops for the P. richardsonii community were about 264 g/m^2 (Garrett, unpublished data). In 1982, Elodea biomass was reduced by almost 70 %, being 229 g/m^2 on 27 August. P. praelongus standing crop was reduced to an average of 259 g/m^2, and direct observation indicated that similar reductions occurred in standing crops of other areas.

Marked differences in meteorologic events differentiated the seasonal weather patterns in 1981-1982. In 1982, heavy snow cover in March, coupled with prolonged cool weather, delayed ice-melt for several weeks, until the last week in May. The heavy snow accumulations in March reduced light penetration and, consequently, the growth potential of macrophytes under the ice. Although it is possible that other factors could have caused the biomass crash of Elodea, such as disease (Schulthorpe, 1967), the apparent cause was simply a change in weather. It seems most probably that the density and production of vascular plant communities in Georgetown Lake fluctuate from year to year in response to meteorologic and hydrologic influences, which can significantly affect depth, transparency, temperature, and dissolved substances.

Maximum standing crops in 1974 of a Myriophyllum stand in Rainbow Bay was approximately 305 g/m^2 dry weight (Garrett, 1983), which represents approximately 112 g C/m^2 (using an ash free organic weight factor of 0.80, obtained by ashing at 500 degrees C, and a carbon compositon of 0.46 x organic weight (Westlake, 1969). A similar pattern of seasonal standing crop distribution was obtained for a stand of _M. exalbescens_ in Stewart Mill Bay in 1976, with the difference that biomass development was delayed, probably due to the cooler temperature of the water (16 degrees C vs 19 in other areas). In both areas the annual maximum production was approximately 300 g/m^2 dry weight (= 112 g org C). However, samples from Stewart Mill Bay in 1974 indicate that the average terminal standing crop of the stand could reach 400 g/m^2 (Garrett, unpublished data).

Nutrient status of vascular plants was evaluated by tissue analysis of nitrogen and phosphorous in whole mixed plant samples, whole individual plants, and index segments of _Elodea canadensis_, _Ceratophyllum demersum_, and _Myriophyllum exalbescens_ (Garrett, 1983). Gerloff and Krombholz (1966) estimated critical nitrogen concentrations for whole plants as low as 1.3%; the comparable phosphorous value was 0.13%. Subsequently, Gerloff (1973) estimated critical concentrations of N and P in index segments of _Elodea occidentalis_ at 1.4% N and 0.10% P. Critical values for _Ceratophyllum demersum_ were 1.3% for N and 0.10% for P. _Myriophyllum spicatum_ had critical levels of 0.75% N and 0.07% P. Wilson (1972) estimated a critical tissue P-concentration for _M. exalbescens_ of 0.08 % and a critical N-concentration of about 1.0 %.

Mixed plant samples from Georgetown Lake contained 0.10-0.50 % P, with an average of 0.25%, and an average of 2.87% N. Index segments of C. demersum contained an average of 0.36% P. Index segments contained of E. canadensis contained 2.48% N and 0.19% P. P. praelongus contained the highest average P-concentration, 0.45%, and M. exalbescens contained 0.28%. Although the concentrations are not directly comparable because of species differences, these values indicate that aquatic vascular plants in Georgetown Lake are not nutrient limited by N or P.

Community primary productivity and respiration were measured by the diurnal pH-CO_2 method in 1981. Summary of results is shown in Table 33. Benthic vascular plant communities and associated periphytic algae dominated the system in terms of biomass productivity and community respiration. The average gross oxygen production by phytoplankton communities at station I was 0.19 g O_2/m^3/day, which at a mean depth of 4.84 m, is equal to 0.92 g O_2/m^2/day. This compares to the average gross oxygen production by unenclosed macrophyte communities at station V (Elodea) of 10.9 g O_2/m^2/day, and gross oxygen production by a similar enclosed macrophyte community (E-5) of 8.8 g O_2/m^2/day.

High rates of oxygen production were balanced by high rates of community respiration in macrophyte communities. Daily respiration of macrophyte communities, periphyton, and sediment averaged 7.2-7.4 g O_2/m^2/day. This is approximately 68 % of the gross oxygen production, leaving a net oxygen production of 1.5-3.5 g O_2/m^2/day.

Table 33. Average Community metabolism measured for benthic macrophyte and algal communities 3 July-17 September, 1981. Gross oxygen production equals actual daylight oxygen production plus respiration corrected for the time period of photosynthetic activity.

	Gross production	Daily Respiration	Net Production
Station V	10.9 g $O_2/m^2/d$	7.2 g $O_2/m^2/d$	3.7 g $O_2/m^2/d$
Enclosure 5	8.8 g $O_2/m^2/d$	7.4 g $O_2/m^2/d$	1.4 g $O_2/m^2/d$
Station I	0.19 g $O_2/m^3/d$	0.5 g $O_2/m^3/d$	-0.3 g $O_2/m^3/d$
Enclosure 1	2.6 g $O_2/m^2/d$	10.4 g $O_2/m^2/d$	*1

*1 Production rates in Enclosures were highly negative until 27 August due to the decomposition of enclosed macrophytes. Positive rates of gross production were not measured prior to that date.

Net phytoplankton oxygen production measured in April, 1982, was greater than the average daily net oxygen production measured June-August, 1981. This result reflects the maximum standing crops of phytoplankton attained in late spring (Tables 35-37 and 38). Moll and Stoermer (1982) observed maximum photosynthetic rates at depths coinciding with increased availability of nutrients, but below optimal light intensity. The high photosynthetic rates observed under the ice may be the result of increased nutrient availibility. Daily respiration rates of phytoplankton at Station I averaged 0.51 g O_2/m^3/day, meaning that on the average planktonic respiration was greater than photosynthesis. This agrees with the results obtained by Knight (1980), who found the same condition in 1973-74 for Georgetown Lake plankton communities.

Considering the high rates of production obtained for macrophyte communities in 1981, it is apparent that the benthic macrophytes are driving the lake oxygen and carbon metabolism. Garrett (unpublished data) found an average rate of gross oxygen production for the P. praelongus community of 2.60 g C/m^2/day, equivalent to approximately 7.6 g O_2/m^2/day in 1974.

The highest rates of gross oxygen production by algae was observed in the shallow experimental enclosures in which most of the macrophytes died, dissolved inorganic nutrients increased drastically, and high standing crops of chlorophyll were observed (14-26 ug/l). The maximum rate of gross photosynthetic oxygen production observed was 2.6 g C_2/m^2/day, at a depth of 2 m equaling 1.3 g O_2/m^3/day. Assuming a photosynthetic quotient of 1.1, this is equivalent to approximately 0.44 g C/m^3/day. If this volumetric rate of production were maintained throughout the average water column of 4.85 m in Georgetown Lake, algal productivity could approach that of macrophytes. Due to attenuation of light by high plankton standing crop and suspended detritus which would accompany such conditions, it is unlikely that algae can obtain such levels of productivity. A complicating factor is that part of the oxygen production in Enclosures 1-4 was due to periphyton which grew profusely on the walls of the enclosures.

The values are within the range of productivity by benthic plant communities as measured by Park, et al (1961), Odum and Wilson (1958), and Copeland and Whitworth (1963), of 7-27 g O_2/m^2/day, using the diurnal method on unenclosed communities. It is apparent that most of the primary productivity in Georgetown Lake is at this time accomplished by benthic macrophytes and associated periphyton. The high rates of planktonic respiration observed in 1981 and by Knight in 1973 and 1974 give evidence that some of the macrophyte production is being cycled into the planktonic community. Also, Geer (1977) in a study of zooplankton production in Georgetown Lake, found that zooplankton productivity of biomass in many cases was almost equal to phytoplankton productivity, a situation which would call for almost complete conversion of algae to zooplankton. It is obvious that part of the zooplankton production is being supported by detritus cycled from the benthic community, the original source of which is macrophytes.

The values obtained indicate that benthic macrophytes are indeed the major primary producers in Georgetown Lake, and are apparently capable of productivity rates capable of driving planktonic respiration to the levels suggested by Knight (1980) through detrital coupling. Knight reported an average planktonic respiration of 2.91 g O_2/m^2/day in Georgetown Lake during the ice free period, which he found equivalent to 2.68 g C, obtaining a respiratory quotient of 0.41. Similar anomalies have been reported for marine waters by Odum and Wilson (1958), suggesting a strong anaerobic component in plankton respiration, which might be expected if detrital components in the free water were derived from sedimentary sources.

Assuming an efficiency of 60-70% by aquatic macrophytes (Klarich, 1979), that macrophytes are responsible for 90% of the primary production of benthic communities (Catteneo and Kalff, 1980), organic weight equal to 80% of dry weight, and organic carbon equal to 46% of organic weight, the productivity estimate could result in the accumulation of a minimum terminal standing crop of 650 g dry weight/m^2 terminal standing crop in macrophyte biomass. Comparing this to observed value of 735 g dry weight/m^2 at station V, this rate of oxygen production and carbon fixation appears a reasonable estimate.

Respiration values can be attributed primarily to sediment (Hargreave, 1971), thus it appears that Garrison (1976) is correct in his assessment that carbon fixed during the summer growing season carries over through the winter to be respired the following summer, when water temperatures allow higher rates of bacterial metabolism.

These rates of production are also sufficient to account for the minimum calculated rate of sedimentation, 550 g dry matter/m^2/yr, at least, if not more, considering the $CaCO_3$ and silicate components.

PHYTOPLANKTON STANDING CROP AND TAXONOMY

The 52 taxa which were identified to genus level or below are presented in Table 34. The divisions Chlorophyta and Chrysophyta were the most commonly encountered, with members generally present in every sample. The Euglenophyta were represented by only one member, an unidentified species of Trachelomonnas. Two species of Pyrrophyta were observed, and although they wre present only periodically, they occasionally made a substantial contribution to the total cell volume. The remaining two groups, the division Cyanophyta and the class Cryptophyceae were each observed in approximately half of the samples.

Phytoplankton standing crops expressed as cell volumes at stations I, V, and Enclosure 1 are presented in Tables 35-37, respectively. Concentrations of phytoplankton chlorophyll a are shown in Table 34. Phytoplankton standing crop (both cell volume and chlorophyll) at station I was characterized by a strong peak on 12 August, 1981 and a minor peak on 1 May, 1982. The August bloom was composed of approximately 75% diatoms (Fragilaria crotonensis) and 25% dinoflagellates (Ceratium hirundinella). Subsequent to 12 August, chlorophyll remained relatively high (5 ug/l) until 13 October. The minor pulse that occurred in May was also composed mostly of diatoms (Cyclotella catentata), with the remainder being Cryptomonas erosa. The maximum observed density of blue-green algae occurred on 22 September, 1981, as Microcystis sp. and Anabaena circinalis.

Table 34. Phytoplankton taxa observed in samples from Georgetown Lake, Montana, during 1981 and 1982. Representative cell volumes are given for all taxa which were present in sufficient abundance to contribute to the total cell volume calculations. Volumes given in um^3.

TAXA	REPRESENTATIVE CELL VOLUME
Division Chlorophyta	
Class Chlorophyceae	
Carteria sp.	
Chlamydomonas sp. Ehrenberg	52
Volvox aureus Ehrenberg	18200[a]
GLoeocystis sp.	26
Pediastrum boryarium (Turp.) Meneghini	
Ankistrodesmus falcatus (Corda) Ralfs	15
Chodatella sp.	
Chlosteriopsis longissima Lemmerman	1059
Oocystis sp.	400
Quadrigula lacustris (Chod.) G. M. Smith	70
Tetraedron minimum (A. Brown) Hansging	40
Scenesdesmus sp.	48
Spirogyra sp.	
Staurastrum sp.	
Cosmarium sp.	
Division Euglenophyta	
Class Euglenophyceae	
Trachelmonas sp.	526
Division Chrysophyta	
Class Chrysophyceae	
Mallomonas alpina Fascher, Ruttner	1963
Class Bacillariophyceae	
Order Centrales	
Cyclotella antiqua W. Sm.	565
C. catentata Brun.	123
Stephanodiscus astrea (Ehr.) Grun.	2000
Order Pennales	
Asterionella formosa Hass	382
Diatoma (De Cand.) sp.	
Fragilaria capucina Desm;.	531
F. construens (Ehr.) Grun.	269
F. crotonensis Kitton	502
Synedra capitata Ehr.	23800
S. acus Kutz.	250
S. acus var. *angustissima* Grun.	1000

S. ulna (Nitz.) Ehr.	1937
Achnanthes sp.	
Cocconeis placentula Ehr.	353
Navicula sp.	
Pinnularia sp.	
Gomphonema constrictum Ehr.	1000
G. sphaerophorum Ehr.	1000
Cymbella sp.	
Epithemia sorex Dutz.	3421
E. turgida (Ehr.) Kutz.	20106
E. zebra (Ehr.) Kutz.	393
Rhopoladia gibba (Ehr.) O. Mull.	110835
Division Pyrrophyta	
Class Dinophyceae	
Peridinium cinctum (Muell.) Ehr.	40000
Ceratium hirundinella (Muell.) Duj.	37396
Division Cyanophyta	
Class Mixophyceae	
Anacystis sp.	344[b]
Microcystis sp.	400[c]
Gomphosphaeria sp.	28
Arthrospira sp.	
Anabaena circinalis Rabenhorst	14
A. flos-aquae (Lyngbye) DeBrebisson	34
Division Uncertain[d]	
Class Cryptophyceae	
Chroomonas Nordstedtii Hansgirg	50
C. ovata Ehr.	2500

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[a] Volume is for average colony of 280 cells.

[b] Volume is for average colony of 132 cells.

[c] Volume is for average colony of 116 cells.

[d] This class is p{laced in the division Pyrrophyta by Prescott (1962) but Bold considers it to be a separate division, the Cryptophycophyta.

Table 35. Phytoplankton standing crops at site I, Georgetown Lake, Montana, during 1981 and 1982, by algal division. expressed as cell volume/water volume (mm^3/m^3 or $10^6 \mu m^3/l$). Dashed entries represent standing crops of less than 1.0 mm^3/m^3 and blank entries indicate failure to detect a particular division on a particular date.

	************************1981************************								*************1982*************				
DIVISION	6/30	7/14	7/28	8/12	8/25	9/09	9/22	10/13	1/30	2/27	3/25	5/01	6/15
CHLOROPHYTA	4.5	34.5	3.3	34.0	77.6	136.0	27.4	78.5	3.5		---		1.4
EUGLENOPHYTA	47.0	1.7		4.8		9.5		9.5					35.5
CHRYSOPHYTA		---	43.9	1440.0	181.0	80.7	128.0	27.4	6.5	5.3	56.8	222.0	75.6
PYRROPHYTA	50.0		84.8	509.0									
CYANOPHYTA		---		---	11.5	28.0	71.9	---			24.9		
UNCERTAIN[a]	2.5	32.3	150.0	30.6	72.7	47.4	15.3	44.0	5.9	4.0	19.9	76.3	9.0
TOTAL	104.0	68.5	282.0	2018.4	342.8	301.6	242.6	159.4	15.9	9.3	101.6	296.3	121.5

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[a] This group's members all belong to the class Cryptophyceae. Prescott (1962) has included them in the Pyrrophyta but Bold (1978) considers them a separate division, the Cryptophycophyta.

Table 36. Phytoplankton standing crops at site V. Georgetown Lake, Montana, during 1981 and 1982, by algal division, expressed as cell volume/water volume (mm^3/m^3 or $10^6 \mu m^3/l$). Dashed entries represent standing crops of less than 1.0 mm^3/m^3 and blank entries indicate failure to detect a particular division on a particular date.

	1981									1982				
DIVISION	6/30	7/07	7/14	7/28	8/12	8/25	9/09	9/22	10/13	1/30	2/27	3/25	5/01	6/15
CHLOROPHYTA	---	76.5	--	---	3.3	35.9	13.6	12.7	270.0			---		
EUGLENOPHYTA	---	1.6		1.6					1.6					25.3
CHRYSOPHYTA	5.8	---	19.4	2200.0	579.0	1100.0	259.0	54.8	30.5	682.0	725.0	1120.0	6800.0	68.6
PYRROPHYTA					170.0	56.5		60.5						
CYANOPHYTA	---			1.1	---	4.8	11.5	57.0	---					
UNCERTAIN[a]	---	1.5	21.0	50.0	24.3	15.2	11.3	33.2	25.7	66.8	63.8	39.1	105.0	---
TOTAL	5.8	79.6	40.4	2252.7	776.6	1212.4	295.4	218.2	327.8	748.8	788.8	1159.1	6905.0	93.9

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[a] This group's members all belong to the class Cryptophyceae. Prescott (1962) has included them in the Pyrrophyta but Bold (1978) considers them a separate division, the Cryptophycophyta.

Table 37. Phytoplankton standing crops at site E1, Georgetown Lake, Montana, during 1981 and 1982, by algal division, expressed as cell volume/water volume (mm^3/m^3 or $10^6 \mu m^3/l$). Dashed entries represent standing crops of less than 1.0 mm^3/m^3 and blank entries indicate failure to detect a particular division on a particular date.

	************************1981************************								**************1982**************				
DIVISION	7/07	7/14	7/28	8/12	8/25	9/09	9/22	10/13	1/30	2/27	3/25	5/01	6/15
CHLOROPHYTA	---	7.2	30.8		---	15.8	1340.0	2960.0	---			---	7.8
EUGLENOPHYTA			1.1				473.0		14.2		14.2	---	7.1
CHRYSOPHYTA	144.0	39.1	340.0	125.0	222.0	18.3	72.9	2.0	36.0	83.7	30.6	10.5	1590.0
PYRROPHYTA				151.0									
CYANOPHYTA		1.2	3.0			---							
UNCERTAIN[a]		197.0	85.0	62.6	1040.0	1990.0	68.2	159.0	16.0	33.6	43.4	72.6	49.9
TOTAL	144.0	244.5	459.9	338.6	1262.0	2024.1	1954.1	3121.0	66.2	117.3	88.2	83.1	1654.8

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[a] This group's members all belong to the class Cryptophyceae. Prescott (1962) has included them in the Pyrrophyta but Bold (1978) considers them a separate division, the Cryptophycophyta.

Station	I	II	III	IV	V	E (1-4)	E5	E6
Date								
30 Jun 81	1.21	3.00	2.13	5.18	1.88	0.28	0.54	****
07 Jul 81	****	****	****	****	1.60	1.29	1.24	0.29
14 Jul 81	1.02	0.98	****	0.74	1.09	0.22	****	0.92
28 Jul 81	2.49	4.67	2.20	12.40	4.09	1.56	****	0.92
12 Aug 81	5.21	3.33	3.17	1.65	2.65	2.97	****	4.72
25 Aug 81	3.05	2.57	2.81	4.44	3.39	13.16	2.59	2.78
09 Sep 81	4.49	3.50	2.53	11.81	4.32	26.24	4.08	2.34
22 Sep 81	2.56	6.81	****	4.96	5.48	16.72	6.53	4.92
13 Oct 81	4.31	4.10	5.90	27.94	5.83	17.52	9.05	1.10
30 Jan 82	0.91	****	****	****	6.05	6.73	5.01	0.00
27 Feb 82	0.54	1.93	1.97	1.67	8.60	5.07	4.16	0.00
25 Mar 82	0.36	1.77	1.17	5.16	8.08	3.10	7.05	0.00
01 May 82	3.60	3.41	****	****	4.59	5.26	14.04	3.21
15 Jun 82	6.59	****	6.62	****	5.11	12.04	****	****

Station	I	IV	DE1	DE2
07 Jul 82	3.45	3.87	***	***
21 Jul 82	3.50	3.48	0.53	3.09
28 Jul 82	5.63	3.46	1.90	1.60
03 Aug 82	7.24	4.81	3.11	2.54
13 Aug 82	5.53	3.78	4.73	4.59
25 Aug 82	11.17	4.47	5.73	8.10

Table 38. Average chlorophyll a concentrations (ug/l = mg/m^3) at sampling sites in Georgetown Lake. In summer, 1982, Station IV was an unenclosed control site at the enclosure (DE1, DE2) location.

The standing crops and chlorophylls at station V were much greater than those at station I during the winter and spring months of 1982. There were also peaks in late summer (28 July, 1981) and early spring (1 May, 1982) at this station, but they were also considerably higher than at station I and were composed almost entirely of diatoms. Rhopalodia gibba represented almost 90% of the biomass of the July pulse and about 38% of the May pulse. The cell volume during the May pulse at station V was the maximum observed for the entire study (6905 mm^3/m^3), although higher chlorophyll concentrations were obtained in Enclosures 1-4. The maximum density observed for any single taxon also occurred during this bloom when Fragilaria capucina reached a standing crop of 3920 mm^3/m^3.

Enclosure 1 was adjacent to station V so that depth, bottom morphology and chemistry, and macrophyte community structures were similar at the outset. The 1981 biomass peak in Enclosure 1 was delayed until August when a bloom of Cryptomonas erosa was subsequently followed by a very dense bloom of Volvox aureus that persisted into October. Diatoms remained at relatively low levels in Enclosure 1 until the last sampling date, 15 June, 1982, when a moderately high crop (1520 mm^3/m^3) of Synedra acus appeared. The populations of Cryptophyceae in Enclosure 1 on 25 August and 9 September 1981 were fully an order of magnitude higher thann those observed at any other station or date. Cryptomonas erosa represented 81% and 90% respectively, of the total cell volumes.

The most notable features of the results are the differences in phytoplankton community structure and time of biomass and chlorophyll peaks between the enclosures and the unenclosed stations. The phytoplankton communities at stations I and V possess common traits despite differences in standing crops. The biomass maxima at these unenclosed stations were due primarily to diatoms, and at both, peaks in standing crops occurred in late July or early August and in early May. Both stations showed persistent but moderate densities of Chlorophyta and Cryptophyceae. The highest densities at Enclosure 1, on the other hand, were composed of Chlorophyta and Cryptophyceae. In 1981, the standing crop as indicated by chlorophyll concentrations in Enclosures 1-4 increased through the entire summer and fall without showing the fluctuations typical of stations I and V. This is probably to stabilization of higher nutrient levels in the enclosures. The spring increase in standing crop at Enclosure 1 was also delayed relative to stations I and V, but by that time the community had shifted towards diatom dominance.

Phytoplankton standing crops at stations II-IV followed a pattern similar to that at station I, with temporal shifts in the development of maxima. Chlorophyll peaks occurred 28 July at stations II and IV, and on 9 September and 13 October at station IV. In general, average chlorophyll concentrations at all stations increased susequent to 12 August. This increase seemed to follow an increase in ammonia nitrogen concentrations, which was attributed to bioactivity in the shallow littoral plant beds.

It seems clear that the environmental modification caused by the enclosure had a profound impact on phytoplankton communities. Concentrations of inorganic nitrogen and phosphorous increased to levels above that observed at any of the open water sites during the ice free season, and alkalinities were also considerably higher while pH's were lower, which would increase the availability of inorganic carbon. The communities which evolved in the enclosures seem representative of responses common to eutrophication, in that the plankton community shifted from one in which diatoms were a dominant feature to one in which Chlorophyta and Cryptophceae were the dominant feature. It is significant that a taxonomic shift back toward diatom dominance seemed to occur over the winter, possibly in response to a reduction in dissolved organic matter, as considerable mineralization occurred over the winter months. It is not possible at this time to choose one or even several factors which would allow a firm statement to be made about what caused the changes in the enclosures; however, the results provide some useful insight into the possible outcome of a large scale macrophyte control project.

Knight, et al (1975) reported phytoplankton standing crops in Georgetown Lake during 19783-75 as cell volume per area of sediment surface. Assuming they used a mean depth of 4.89 m (Knight, 1980), a comparison of their standing crop estimates can be made with those from this study. Seasonal patterns of standing crops observed were very similar to those in 1981-82, namely a strong peak of biomass in late July or August and a weaker peak in the spring just before ice melt. In 1973, the summer peak came later, in September, and was composed of a very high density Anabaena population. Their estimate of Anabaena cell volume, 38,855 mm^3/m^3, is almost six times greater as the largest total community cell volume observed in 1981-81. In general, the standing crops they observed in 1973-75 appear to be a factor of 2 greater than the 1981-82 observations.

There are two obvious differences in the major aspects of the phytoplankton communities between the two time periods. In 1981, the Cyanophyta did not comprise a major potion of the phytoplankton community at any of the stations except I and V on 22 September, 1981, being limited on that date to about 25% of the total cell volume. Knight, et al (1976), found blue-greens to be a dominant feature of the phytoplankton community on several occasions. Phytoplankton standing crops were reduced by a factor of about 2 throughout the period of observation in 1981-82.

Algal Chlorophyll, Productivity of Plant Communities, and Fertilization

The enclosure experiment carried out during the summer of 1982 utilized two enclosures 16 feet (4.8 m) deep, one of which was fertilized weekly with inorganic nitrogen as ammonia and inorganic phosphorus. N:P ratio was approximately 8:1 by weight (17:1 atoms). The total nitrogen loading was 11.6 g/m^2; the total phosphorus loading was 1.65 g/m^2. Fertilization began on 21 July and continued through 9 September. The fertilization schedule and target concentrations of nitrogen and phosphorus are shown in Table 39.

Table 39. Fertilization schedule for experimental enclosures in 1982.

Date	N added	[N]	N_T	P added	[P]	P_T
21 Jul	2.427	0.08	0.44	0.347	0.01	0.063
28 Jul	2.427	0.08	0.88	0.347	0.01	0.126
03 Aug	12.145	0.50	3.08	1.735	0.05	0.440
14 Aug	24.270	1.00	7.48	3.470	0.10	1.069
26 Aug	12.131	0.50	9.68	1.733	0.05	1.383
09 Sep	10.533	0.40	11.59	1.505	0.05	1.656

[N] is nitrogen concentration added in mg/l; [P] is phosphorus concentration added in mg/l. N_T and P_T are the total loadings of N and P per m^2 to date.

Concentrations of ammonia nitrogen and phosphorus at all stations sampled in 1982 are given in Tables 40 and 41 respectively. Concentrations of total phosphorus at station I and IV and in the unfertilized enclosure, DE1, were comparable to those obtained in 1981. However, inorganic (ortho) phosphorus at station I was considerably higher than observed in 1981, reaching a maximum of 15 ug/l on 25 August. Concentrations of inorganic phosphorus were lower at station IV, the enclosure control, and in DE1, the unfertilized enclosure. In spite of heavy loading of phosphorus and nitrogen in DE2, concentrations of dissolved nitrogen and phosphorus did not begin to increase until 15 August, after which total phosphorus increased to almost double the values at other stations (38 ug/l). Inorganic nitrogen (ammonia) remained at levels comparable to the controls in spite of heavy loading, indicating that nitrogen was being taken up and converted to organic form as rapidly as it was added.

Station	I	IV	DE1	DE2
09 Jul 82	5	17	**	**
21 Jul 82	0	0	13	0
28 Jul 82	0	0	0	0
03 Aug 82	0	0	0	0
15 Aug 82	0	0	0	0
26 Aug 82	4	3	7	3
07 Sep 82	11	7	11	7

Table 40. Average concentrations of ammonia nitrogen (ug/l N) in samples from Georgetown Lake in summer, 1982.

Station	I				IV				DE1				DE2			
	I	D	T	P	I	D	T	P	I	D	T	P	I	D	T	P
09 Jul 82	**	10	25	**	**	12	23	**	***************				****************			
21 Jul 82	8	6	23	9	2	9	16	5	2	14	22	6	2	9	19	8
28 Jul 82	13	5	23	5	0	8	18	10	0	10	22	12	0	9	15	6
03 Aug 82	0	9	21	12	9	7	18	3	0	11	19	8	0	13	28	15
15 Aug 82	2	7	19	10	4	6	15	5	3	7	20	10	6	10	20	4
26 Aug 82	15	**	22	**	4	**	20	**	4	**	20	**	12	**	45	**
07 Sep 82	5	8	21	8	4	8	18	6	5	7	27	15	7	10	38	21

Table 41. Average phosphorus concentrations (ug/l) at sampling stations in Georgetown Lake during summer, 1982. I = Inorganic, D = Dissolved unreactive, T =Total, P = Particulate (Total - Inorganic - Dissolved unreactive). ** Indicates no data.

Ammonia at station I and IV followed the same pattern observed in 1981, in that concentrations were undetectable until early August, when a gradual increase began. Ammonia concentrations in the unfertilized enclosure, DE1, were comparable to stations I and IV.

In the early part of the fertilization experiment, very little response in phytoplankton standing crop was noted. Chlorophyll concentrations remained at levels comparable to the control enclosure and unenclosed stations. Significant response in phytoplankton standing crop to fertilization was not noted until 25 August, 1982. Chlorophyll concentration in the fertilized enclosure was 8.1 ug/l, 41 % higher than the unfertilized enclosure, 5.73 ug/l (Table 38). The unenclosed control at the experimental site was 4.47 ug/l, thus both enclosures showed an enhancement of chlorophyll over the unenclosed control.

On the same date chlorophyll at station I was 11.17 ug/l, higher than any value obtained at this station in 1981 and directly comparable to values at this station in 1973 (Knight, 1980). Chlorophyll at station I was consistently higher throughout the summer of 1982 than in 1981, and was also higher than chlorophylls obtained at the experimental control site and in both enclosures, both fertilized and unfertilized. Mean extinction coefficients were increased by 50-60 % at station I, and were comparable to those obtained in the experimental enclosures.

Measurements of community productivity carried out at the experimental station in 1982 during August showed that phytoplankton gross primary production (as oxygen) was stimulated approximately 274 % in DE2 over that measured in DE1 (5.13 and 1.87 g O_2/m^2/day respectively), and 132 % relative to the unenclosed control station (3.89 g O_2/m^2/day). Gross community oxygen production in DE2 was stimulated by 172 % relative to that in DE1, of which 63 percent of the increase was was due to phytoplanktonic and 9 % due to benthic sources. These results indicate that the benthic community, although it apparently took up most of the added nutrients, showed a relatively slight response in productivity, while the phytoplankton community responded strongly. In measurements of phytoplankton metabolism, interference by epiphytic algae was assumed to be negligible, due to the short period of incubation using the smaller vinyl columns.

These results indicate that in-lake disposal of macrophytes removed by mechanical harvesting or herbicide treatment at a moderate level (up to 500-700 acres/year) would not be expected to stimulate a significant response in growth from the remaining benthic communities and a relatively moderate response from phytoplankton, which would probably be beneficial in terms of improving fish production and somewhat repressing additional macrophyte growth by competition for light.

The fertilization experiment added dissolved inorganic nitrogen and phosphorus, which is probably more available to phytoplankton than macrophytes. Harvested macrophytes laying on the bottom might produce nitrogen and phosphorus more available to the remaining benthic community. Collection of cut plants and composting would eliminate this.

SEPTIC LEACHATE SURVEY/DYE STUDY

Results of the dye study were negative. No dye was found entering the lake from any site.

Results from the septic leachate survey using the Endeco Septic Leachate Detector (see Appendix 6) were largely negative. A total of nine possible leachate plumes were identified and mapped (Fig. Q). Plume site numbers 1, 2, and 4-8 appeared to be associated with septic tank drainfields. Plume site 3 was due to discharge from the wetland area adjacent to the reservoir and North Fork of Flint Creek. Plume site could be associated with any one of several sources in the immediate vicinity. Results of the septic leachate survey were transmitted to the Tri-County Sanitarian.

These plume sites were subsequently sampled for water chemistry and bacteriological contamination. Bacteriological analysis did not indicate contaminataion by micro-organisms from human fecal material. No fecal streptococci were found and fecal coliforms were well below state criteria in all cases. A copy of the laboratory report on microbiological results is found as Appendix 7. Chemical analyses indicated no enhancement of ammonia, phosphorus, or chloride, except at Plume 3, where a slight increase of chloride was observed. Similar chloride increases were observed in the macrophyte enclosures 1-4, apparently due to ion exchange reactions between water and sediment under low oxygen conditions. Since biological and chemical conditions would be similar in the marshy area adjacent

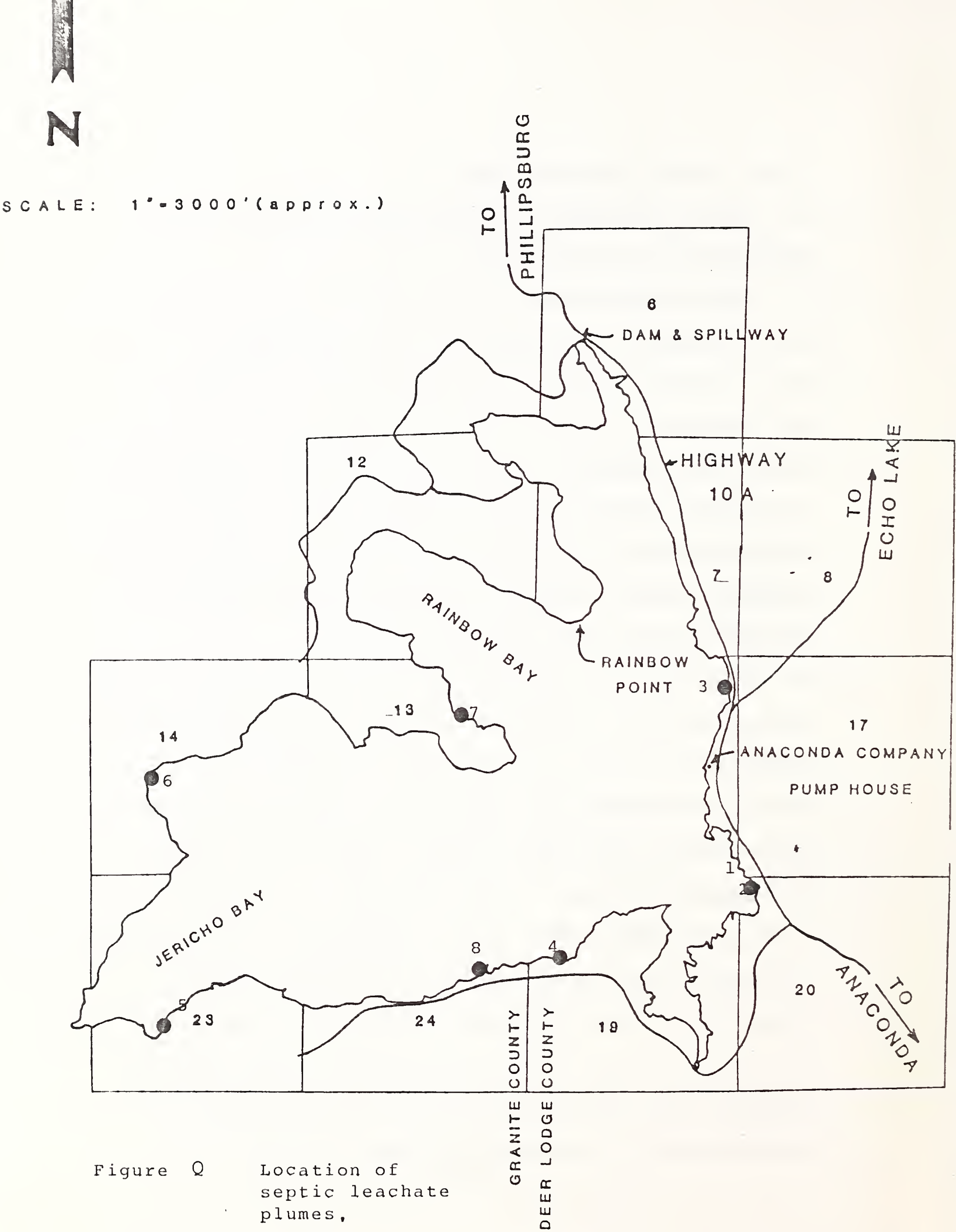

Figure Q Location of septic leachate plumes.

● - potential plume sites identified. See text for discussion.

to Highway 10A and Flint Creek, from which this water is discharged via a culvert, these natural phenomena are most probbly the cause of the increased chloride.

Additional verification of Plume site 2 as a septic leachate plume area, probbly intermittent, by the presence of a sludge deposit several feet thick adjacent to the discharge area. Plumes 6 and 7 were classified as inactive, that is, not discharging at the time of detection. Plume 8 was not verified as a septic leachate plume by water chemical analysis or the presence of sludge. The substrate at this site is cobble. No enhancement of algal growth was observed. Kokanee salmon were observed spawning on the site and in the immediately surrounding area in October.

Some problems in operating the Endeco Septic Leachate Detector were encountered. The submersible pump frequently became clogged with periphytic and benthic algae, causing false spikes in the fluorescence channel. During the September run, dissolved organic matter from decaying vegetation interferred with detection of fluorescence from potential plumes. Careful interpretation of conductance data and fluorescence:conductance ratios was necessary to differentiate false or questionable data. The location of inactive plumes, which is largely dependent on fluorescence, was not possible during this portion of the survey. The identification of inactive plumes during July, while practical in some areas where plant growth is not excessive, is questionable in areas of heaviest macrophyte growth, as exemplified by Plume 6.

The total number of plumes identified and the results of chemical sampling indicate septic tanks are not major sources of nutrient loading. Additional calculations on the nutrient loading potential of septic systems adjacent to the reservoir are given in the Nutrient Budgets section.

LAND USE

Relationships of Land Use to Water Quality

The chemical and biological characteristics of lakes are related to the geochemical characteristics of the surrounding basin due to the downstream flow of dissolved materials derived from the weathering and dissolution of rocks and minerals which are exposed to water draining the area, as well as the decomposition and suspension of animal and vegetable components. Cultural activities with potential for impacting the trophic state and water quality of Georgetown Lake include logging, mining, agriculuture (grazing) and recreational use and development. The effects on water quality are usually due to the introduction of silt from increased surface erosion or the discharge of contaminating materials such as sewage, mining, or industrial wastes into surface or groundwater. There is also the possibility of direct effects on water quality from recreational use, such as shoreline erosion caused by boat wakes or excessive vehicule traffic.

The Clean Lakes Program is primarily addressed toward conditions which impact the usefulness of a lake by affecting the biological productivity (trophic state) through the process of cultural eutrophication, although it does not exclude other problems (Section 6.0, Clean Lakes Guidance Manual). This is due to fundamental differences in the nature of eutrophication, compared to such problems as bacterial contamination, introduction of toxic substances (such as heavy metals), or excessive siltation.

There is no industrial activity at present in the Georgetown Lake basin. The nearest industry of any significance to water quality was the Anaconda Company Reduction Works, 16 miles from the reservoir in the town of Anaconda. This facility used Georgetown lake as a storage reservoir for industrial process water. There are no point source discharges, major mining activity, or significant agricultural activities in the basin upstream from Georgetown Lake. Some mining has occurred in the past and exploration is expected in the near future, as mineral deposits of economic significant are indicated in the area (U. S. Forest Service, Deer Lodge N. F. Planning Team, unpublished data; Ingman and Bahls, 1979). Timber harvest also has some potential for impacting water quality, primarily through increases in erosion and siltation to the North Fork of Flint Creek. The potential impacts associated with recreational use and developement are usually related to increased erosion during construction, increased surface runoff due to removal of natural vegetation and construction of roads, parking areas, and walkways, and increased nutrient export due to domestic sewage wastes and fertilizers.

Mathematical equations have been developed to relate parameters of water quality reflecting trophic state to characteristics of the drainage area and changes in land use. Because phosphorus and nitrogen are essential to plant growth, are commonly limiting nutrients in lakes, and are often affected by cultural land uses, most such equations deal directly with increases in phosphorus or nitrogen loading. Other factors, such as depth, suspended sediment, and sediment chemistry, also contribute to determining a lake's condition as to biological productivity. An increase in nuturient loading may or may not affect the trophic state, depending on the interplay of these and other factors. One of the major problems in developing and applying these equations is adequately determining the relationship between changes in biological condiditions, water quality, nutrient "loading" from natural and cultural sources, and land use. Under conditions involving extensive development by man, models may help define the best strategy to improve water quality by changes in management and planning. Under natural unspoiled conditions, models may offer the opportunity to prevent the deterioration of environmental quality before it occurs.

Other conditions do not lend themselves to direct determination, therefore models are not easily derived to express the relationships involved. Examples are estimation of nutrient inputs from "non-point" sources of nutrients, such as septic tank drainage or input from "dry fallout", such as dust. Another problem in the application of available models is that the problem condition, such as excessive growth of rooted aquatic vegetation, may not be directly related or immediately responsive to changes in nutrient loading because of internal sediment nutrient supplies which mask an overall change in nutrient input. Considering these problems, models may or may not provide guidelines for management relative to land use.

Land Cover and Use Classification in the Georgetown Lake Basin

The Forest Service has classified government owned lands in the Deer Lodge National Forest under their preliminary land type inventory (Ruppert, 1980). This system divides up areas into general use-capability areas, based on topography, soils, hydrology, and vegetation type. A total of 373 land types were identified in the Deer Lodge National Forest, many of which occur in the Georgetown Lake basin. Distinct land types may have many common characteristics which make them essentially the same for management purposes, such as vegetative cover, soil erodability, and soil permeability. The total number of vegetative types distinguished was 66, of which many are different phases of the same general type; for example Douglas fir timber type has a number of "phases", based on the kinds of vegetation with which Douglas fir occurs.

Soils in the Georgetown Lake drainage were classified by the Forest Service as being in the "Low" and "Moderate" erosion potential classes. This is reflected in the low total suspended solids (a measure of sediment and silt) measured in the North Fork of Flint Creek.

For purposes of the Clean Lakes Project, land cover/use was classified into seven classes. Classifications were made using USGS 7.5 minute quad maps, black and white aerial stereo photographs at a scale of 1:24000, and data from the Forest Service land use classification program. The classifications utilized are given in Table 43.

The Georgetown Lake basin was divided into seven sub-drainages and the percent of each land use/cover type in each subdrainage determined by planimetry. The results are shown in Table 44 by subdrainage. Table 45 summarizes the total percent of each land use/cover type in the entire basin.

The most common land use/cover type in the basin is coniferous forest. For study purposes, rock outcroppings and talus slopes were included in this land cover type. Under the Forest Service preliminary inventory, 71 percent of the total area under Forest Service management is considered commercial forest with potentially harvesteable timber resources. Major timber types include lodgepole pine, Douglas fir, limber pine, subalpine fir, and mixed conifers. This comprises over 90 percent of the total forested area.

As of 1981, timber had been harvested from approximately 1400 acres, including 127 acres of private land. The method of operation has been primarily clear cutting in moderate sized blocks. The majority of clearcut areas occurred in the Stewart Mill Creek subdrainage (Area V). All were several miles from the reservoir, so have had little apparent impact on esthetics or water quality. Other small clearcuts have occurred in the Flint Creek subdrainage (Area VII), and several timber sales have been completed, with projected

Table 43 . Land Use and Cover Classifications used in the Georgetown Lake Clean Lakes Project.

Use/Cover Type	Symbol	Description
Coniferous Forest	(CF)	Timbered areas not adjacent to streams, or timbered areas not shown as wetland or riparian
Grassland/Meadow	(GL/M)	All grassland, including wet mountain meadows not in stream bottoms
Clearcut	(CC)	Self explanatory
Riparian/Wetland	(RP/WL)	Wet areas along stream courses around lakes which were identifiable by vegetation
Rural Residential	(RR)	Areas upon which homes have been constructed and an one acre radius around the structures.
Recreational	(REC)	Public campgrounds, picnic areas
Commercial	(CM)	Private commercial facilities

Table 44. Relative areas of land use/cover types in sub-drainages of Georgetown Lake. Subdrainages shown in Fig. __.

Area		% of Total Drainage	Land use/ cover Type	% of Subdrainage	% of Total
I	East Fork 2157 A	6.36	CF	53	3.34
			Gl/M	47	2.97
			RP/WL	<1 (0.4)	0.02
			REC	<1 (0.5)	0.03
II	Blodgett 3640 A	10.73	CF	80	8.62
			GL/M	14	1.50
			RR	6	0.50
			RP/WL	<1 (0.2)	<0.01
III	Edwards 495 A	1.46	CF	71	1.04
			GL/M	4	0.06
			RR	25	0.36
			RP/WL	<1 (0.2)	<0.01
IV	Denton's 746 A	2.20	CF	74	1.63
			GL/M	12	0.26
			RR	12	0.26
			RP/WL	<1 (0.4)	0.01
			CM	1	0.03
V	Stewart Mill Creek 12584 A	37.10	CF	86.2	31.98
			GL/M	4	1.48
			CC	9.2	3.41
			RR	<1 (0.1)	0.04
			RP/WL	<1 (0.3)	0.11
			REC	<1 (0.2)	0.07
VI	Prospect/ Daly Gulch 1693 A	4.99	CF	42	2.10
			GL/M	54	2.69
			REC	<1 (0.2)	0.01
			RP/WL	3.3	0.16
			CM	<1 (0.2)	0.01
			RR	<1 (<.1)	0.01
VII	North Fork Flint Creek 10,223 A	30.14	CF	85	25.31
			GL/M	11	3.31
			RP/WL	2.6	0.78
			RR	1.5	0.45
			REC	<1 (0.4)	0.12
			CC	1.0	0.30
			CM	<0.1	<0.01
VIII	North Shore 2364 A	6.97	CF	32	2.23
			GL/M	54	3.76
			RR	12	0.84
			REC	1.8	0.12
			RP/WL	2	0.15

Total Area 33,902 Acres

additional harvest in this subdrainage of 352 acres. This includes up to 100 acres which will be cleared for ski lifts and runs at the Discovery Basin Ski Area, operating on a special permit from the Forest Service. This will bring the total acreage in this land cover type to approximately 1700 acres.

Table. 45 . Percent of land use/cover classes in the Georgetown Lake Basin.

Land use/cover type	% Total area	Acres
CF	76.19	25,830
CC	5.60	1,900
GL/M	15.97	5,414
RP/WL	1.22	414
RR	2.46	834
REC	0.41	139
CM	0.04	14

Riparian/wetland areas tabulated were associated with Georgetown Lake or the North Fork of Flint Creek. Acreages obtained were less than the Forest Service land inventory indicated because narrow riparian zones along the stream course were not included. Riparian/wetland land cover type was primarily willow-sedge-grass scrub or sedge-grass wet meadows. There are several such wetland areas on the North Fork of Flint Creek indicated by aerial photography (Fig. R) which should be considered critical habitats for water quality management, as they are probably acting as traps for sediment and nutrients from the upper drainage (van der Valk, et al, 1979; Boto and Patrick, 1979). The riparian zone bordering the

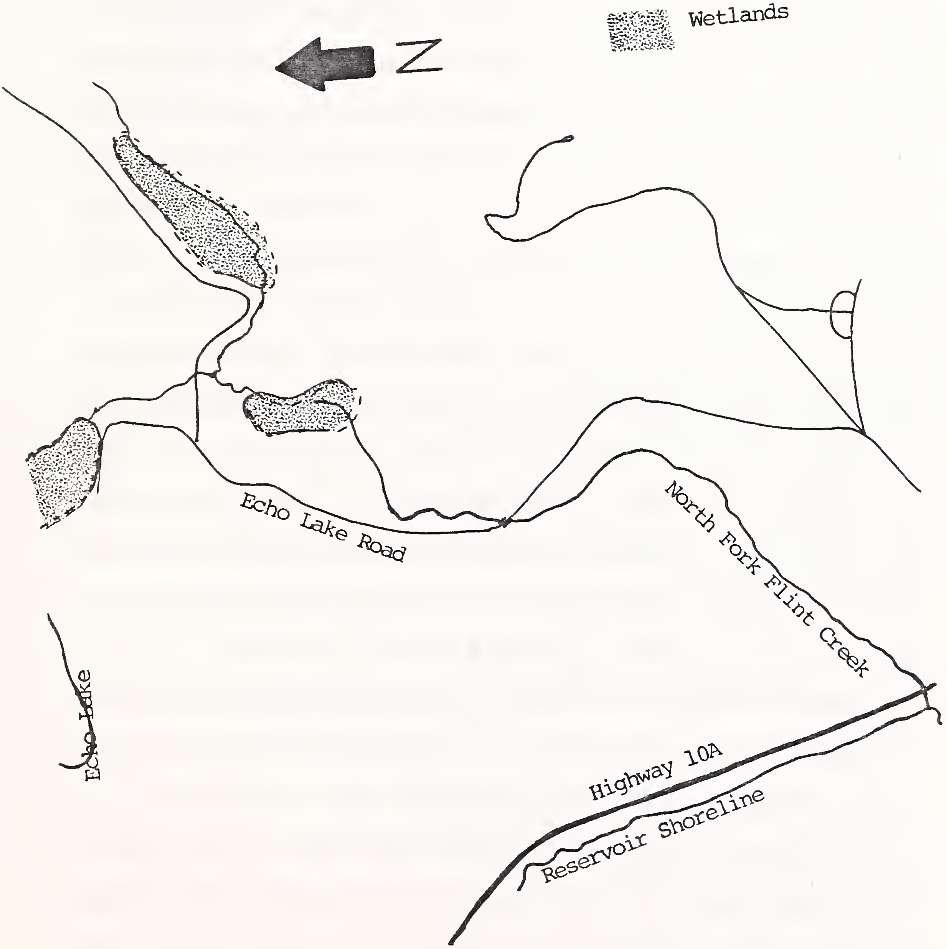

Figure R. Wetlands associated with North Fork of Flint Creek which should be preserved to maintain water quality.

North Fork of Flint Creek should also be considered critical habitat, as it stabilizes soils adjacent to the stream bed during high water and prevents erosion (Allen, 1979). The riparian land cover type also includes a narrow zone bordering the shoreline of Georgetown Lake within which vegetation is influenced by additional moisture seeping from the reservoir or shallow groundwater inflows. In general this riparian zone was considered to be approximately 50 feet wide, although in some areas (such as Stewart Mill Bay and the upper end of Philipsburg and Rainbow Bays, it is considerably wider. The total area of this zone around the reservoir is approximately 78 acres (31.7 ha). It is important in intercepting nutrients and silt from direct surface runoff around the perimeter of the reservoir and protecting the shoreline from erosion. Wetlands in the Stewart Mill Bay area and along Highway 10A in the vicinity of Flint Creek are the only significant wetlands in terms of waterfowl production associated with the reservoir. These areas also contain some shallow marsh habitats which are heavily used by waterfowl in the fall.

The Rural Residential land use type includes subdivision tracts, individual tracts under private ownership, and tracts leased from the Anaconda Company and U. S. Forest Service. The total acreage tabulated in this type was 840. There are a total of ten platted subdivisions within a one mile radius of the reservoir. The average lot size, number of platted lots, and location by section are shown in Table 46. The total number of subdivision lots is 821. The overall average lot size is 0.77 acres; this includes some open areas in the old Eccleston's Subdivision which are not developed, but included in the subdivision boundary. The area occupied by subdivided lots is approximately 632 acres; this does not include access roads and open areas not platted for residential development, or isolated lots under lease or private ownership. The total area under subdivision, including access roads, is estimated at approximately 700 acres.

All recreational residential and commercial development to date utilizes on-site disposal of septic wastes. Waste disposal in all subdivisions approved since 1961 must meet minimum requirements set out under the revised Montana Water and Sewer Facilities Regulation (Regulation 136, adopted in Section 5, Chapter 95, Laws of 1961), as modified in 1963, 1970, and 1973, administered by the Montana Department of Health and Environmental Sciences. These state requirements are supplemented by local and county regulations, which are administered by the local sanitarian. Prior to 1973, subdivisions could be approved with sanitary restrictions on the individual parcels. Guidelines for the minimum lot size requirements for on-site disposal of sewage wastes required 10,000 square feet (0.23 acres) for a system if community water supply was used, and 20,000 square feet (0.46 acres) if both on-site sewage disposal and water supply were used. Subsequent to 1973, the lot size criteria was increased, requiring 20,000 square feet for on-site disposal with community water supply (or vice-versa), and 43,560 (1 acre) for

Table 46. Parameters of subdivisions in the Georgetown Lake area.

Subdivision	County	Range/Township/Section	Number lots	Ave. Lot size
Georgetown	Deer Lodge	5N/13W/17	176	0.08 A
Tract	Deer Lodge	5N/13W/17	39	0.60
Sunset Homesites	Deer Lodge	5N/13W/17	67	0.63
Mountain View	Deer Lodge	5N/13W/8	40	0.60
Denton's Tract	Granite	5N/14W/14	114	0.35
Georgetown Village	Granite	5N/14W/24	27	0.55
Edwards's Tract	Granite	5N/14W/24	117	0.30
			10	1-2
Lakeview	Granite	5N/14W/26	93	0.88
			1	28.1
			1	21.8
Shakopee Heights	Granite	5N/14W/15	49	2.31
Eccleston's*	Granite	5N/14W/14	87	2.1

*Approximate lot size includes unplatted open areas. The actual lots are considerably smaller.

on-site disposal and water supply.

Residential development over the past 15 years has been concentrated in subdivisions. A site survey of Lakeview and Edwards subdivisions in 1982 showed that construction has occurred on 60 lots, out of a total of 210. Of the 117 lots in Edwards tracts, approximately 60 are below the then-existing 20,000 square foot minimum requirement for on-site water supply and sewage disposal (well and septic tank). The maximum number of dwellings that could be put in this tract, without development of community water supply or sewer, is estimated at 87. All of the lots in Lakeview are above the 20,000 square foot minimum requirement that existed at the time of approval, so this development could eventually attain full capacity at 93 dwellings. A site survey of the Georgetown Village subdivision showed that dwellings had been constructed on at least 10 of the lots, and some ground clearing was apparent on several others.

Of the total of 27 lots, 9 are included in Georgetown Village II, which has been approved by the Granite County Planning Board and is now in the process of review by the State Department of Health and Environmental Sciences. Georgetown Village has a community water supply, so all builders can use septic systems. During the residential site survey, 66 dwellings were counted in the Eccleston's/Shakopee Heights area. Of these, 51 were present in the old Eccleston's subdivision in 1970, leaving 15 that have been built since. Additional development in this subdivision is limited to the remaining 20 or so lots, thus most of the additional construction potential on private property in section 15 will be in Shakopee Heights. Because Shakopee Heights was platted subsequent to 1973, lot size requirements were increased to a minimum of 1 acre for well and septic system combinations. The average lot size for this subdivision was calculated at about 2.3 acres. The total development potential is 49 residences.

The old Georgetown subdivision, in Section 17, T5N, R13W, has the largest number of lots (176) and the smallest average lot size (0.08 acres = 3500 square feet). Because of the small lot size and minimum lot size requirements, more than one lot may be required to install a well and/or septic system. Using the 10,000 square foot minimum, the maximum number of single family dwellings that could be built is approximately 60. Because of the age of this subdivision, other regulations relative to minimum lot sizes for well and septic may apply; however, for the protection of personal safety, the 10,000 square foot minimum is adviseable and will probably be used by builders, most of whom own more than one lot. All lots in Mountain View subdivision can be developed.

Additional residential development has occurred as individual residential leases from the Anaconda Company (89) and Forest Service (58), totaling 147 individual tracts. Of the Forest Service leases, 37 are within the immediate proximity of the reservoir shoreline, with the remainder (21) located around Echo Lake. Approximately 5 to 10 company leases are located at Southern Cross. The remainder of the Anaconda Company leases are adjacent to the reservoir.

Construction on these leases is approaching or at the maximum. Construction on approximately 20 Anaconda leases or private, non-subdivision tracts has occurred since 1970, primarily in the Rainbow Point area and along Highway 10A.

There are approximately 10 private owners who have smaller tracts near the reservoir. There are six private owners with holdings at Echo Lake. Allowing approximately 1 acre per ownership under the residential category, the total residential acreage in non-subdivided tracts under private ownership is approximately 16. Assuming the lease tracts are approximately the same size as private, subdivided tracts, or may be considered to influence approximately the same area, they represent another (147x0.77)=113 acres, which may be classified as residential. Of the leases, 48 are located at Southern Cross or Echo Lake, leaving 99 distributed around the reservoir. These leases are scattered around the shoreline of the reservoir and represent the majority of shoreline development. At the time they were granted, there were no restrictions on the construction of individual boat docks, which has resulted in a proliferation of small docks and piers in several areas, notably sections 24, 13, 12, and 6 (Fig. C). A few home-owners have resorted to rip-rapping short sections of the shoreline around their private boat docks to prevent erosion. This is noticeable around Rainbow Point and Piney Point, where boat traffic often passes close to the shore. The only private group boat dock facilities are located at the Butte Boat Club, near the dam, and at Eccleston's, in Ecclestons

Bay. The Butte Boat Club represents an additional 39 residences and approximately 11 acres of residential land use/cover type.

The U. S. Forest Service has frozen all recreational leases; no additional leases will be allowed. The Anaconda Company has offered its recreational leases for sale to the lessees, so is in the process of divesting itself of its small property holdings. The company has also offered at sale the larger parcels it owns in the area, totaling upwards of 30,000 acres, much of which is not in the Georgetown lake basin. However, the company owns approximately 7.15 miles of shoreline (approximately 41 percent of the total), most of which has development potential, which has yet to be developed (Fig. C).

Construction on shoreline residential leases (some of which may pass into private ownership) is reaching capacity. One area in which additional construction may occur on these tracts is in the Fish Hatchery tracts, east of Highway 10A.

Moderate increases in total number of residences built occurred during the period from 1970-1982 in several subdivisions around the reservoir, totaling approximately 42 units. Total construction of new residential units was approximately 75-80; this includes estimated construction in Sunset, Mountain View, Georgetown tracts (Gangiers) of an estimated 20 additional units, and construction of an additional 20 units on Anaconda Company or Forest Service leases. A review of sanitary permits issued for the Georgetown Lake area by the Tri-County Sanitarians Office confirmed this estimate.

The Commercial (CM) land use type occupies approximately 14 acres in the drainage. This does not include the ski runs at Discovery Basin, which were placed under CC or GL/M. Commercial facilities include Stewart's Landing, Denton's Point, the Brown Derby, and Seven Gables . Stewart's Landing and Denton's Point are shoreline facilities offering boat rental and mooring, lodging, grocery and tackle sales, and a restaurant/bar (Denton's). The Brown Derby and Seven Gables are located approximately one-half and one-quarter mile from the shoreline respectively. Services offered include motel facilities (both), a bar (both) and restaurant (Brown Derby).

Residential Use

As part of the septic leachate survey, information on use and characteristics of residential development in the Georgetown Lake area was collected. A questionnaire was developed prior to the dye study, and responses filled in for cooperating homeowners by volunteers who distributed the dye. Information requested included the approximate age of the structure, distance from the shoreline of the reservoir, location by section, approximate use in occupant days by season, and type, size and age of septic system. A sample questionnaire is shown in Appendix 8 .

Approximately 120 questionnaires were returned, all of which were analyzed. Results are shown in Table 47.

Table 47. Residential parameters for the Georgetown Lake area.

Residence Age (Years)	#	%	Lot Size (Acres)	#	%	Type of Use	#	%	Waste Disposal system	#	%
0-5	9	15	<1/2	41	64	Seasonal	62	94	Septic tank	33	59
6-10	8	13	1/2-1	20	31	Permanent	4	6	Cesspool	12	21
11-20	15	25	1-2	2	3				Outhouse	15	27
21-40	17	28	2+	1	1				Other	3	5
40+	12	20							Unknown	1	1

Over 50 percent of the residences surveyed were within 100 yards of the shoreline and over 90 % were within 400 yards (estimated). The questionnaire results indicated that 94% of the residences surveyed were of the "second home" recreational type (indicated by the Seasonal Use category). Cooperating homeowners were asked to estimate the average number of days their residence was used during different seasons, and the average number of occupants when in use. Heaviest use occurred in June, July, and August (about 90 percent of the total occupant days). The average total occupant-days per residence (average number of occupants times the total days occupied per year) was 260, equivalent to about 0.7 occupant-years per residence (260/365). The range of total occupant-days per residence went from a low of ten to a high of four hundred. There are an estimated 20 family residences occupied year-round in the immediate vicinity of Georgetown Lake, and about 10 additional residences with year-round occupants at Southern Cross.

The Recreational land use category includes public campgrounds and picnic areas. The total acreage tabulated was 139 acres. This includes three Forest Service campgrounds around the reservoir, public launching ramps at Red Bridge, Grassy Point, Piney Point, and Phillipsberg Bay, and three areas owned by Anaconda Company which are being used as public campgrounds. These are located on the east and west shores of Jericho Bay, and at Stewart Mill Bay and have a capacity of approximately 80-85 units. Although these privately owned campgrounds are available to the public for the present, this may change if the Anaconda Company sells the property. The total capacity of all available camping facilities is approximately 233 spaces [Denton's (45) + Anaconda (85) + Forest Service (103)]. This number will be reduced to approximately 145 if the Anaconda Company closes their facilities now available to the public. Campground occupancy rates are running about 30-50 percent in Forest Service Campgrounds (personal communicaton, Howard Challinor, Phillipsberg Ranger District, USFS). If it is assumed that other facilities have similar occupancy rates, existing camping facilites could reach capacity in the near future.

Impacts of Present or Past Land Use on Water Quality

The Montana Water Quality Act and Administrative Rules thereof (Appendix 4), administered by the Water Quality Bureau, Department of Health and Environmental Sciences, requires that a permit be obtained to construct, modify, or operate a disposal system, or construct or use any outlet for discharge of sewage, industrial, or other wastes into state waters. DHES may require monitoring of streams or lakes into which discharges empty, the installation of discharge flow controls, or other measures to insure that standards are met. Authorization is also required from DHES for short-term construction or hydraulic projects which may have short-term water quality impacts. Public notice must be given before permits can be issued.

Under Part III of the Montana Water Quality Act, a classification system was established for all public waters in the state of Montana. Georgetown Lake and all tributaries thereto have been classified A1, the highest classification for non-municipal water supply drainages. Standards have been adopted to establish maximum allowable changes in water quality parameters and a basis for controlling discharges of pollutants which might affect uses of lakes and streams. Limits are established for coliform bacteria, dissolved oxygen, hydrogen ion concentration (acidity), turbidity, temperature, suspended sediment and other solids, oils, color, and toxic or other deleterious substances (which may include nitrogen and phosphorus, where applicable) for the protection of human health, aquatic life, and beneficial water uses. For toxic and other deleterious substances, EPA national criteria are used, unless local conditions make more stringent values appropriate.

In December, 1982, new rules were adopted concerning non-degradation of high quality waters (Appendix 4b). Degradation is defined to exclude changes in surface water quality due to "non-point source pollutants from lands where all reasonable land, soil, and water management or conservation practices have been applied." This statement is specifically applicable to the agriculture and timber industries where resource utilization or management may cause some unavoidable effects on water quality.

Water analyses of the North Fork of Flint Creek, Stewart Mill Creek and ground water from shoreline springs do not indicate significant impacts on chemical or physical water quality from logging, mining, or recreational use at the present time. Total suspended solids in the North Fork remained very low during all times of the year, including peak flows, and in fact show no significant correlation with flow volume ($r = 0.2$, $p < 0.8$). Although the potential for timber harvest is great in the Georgetown Lake drainage, existing Forest Service Management policy has placed emphasis on protecting recreational and water quality values. Schmidt (1980, unpublished Situation Analysis, Phosphates and Georgetown Lake, USFS) qualitatively assessed potential impacts of logging and burning, controlled or natural, on export of phosphorus and silt to the North Fork and Georgetown Lake. In view of the low erosion potentials, he concluded that increases in suspended sediment and phosphorus in the stream would be moderate and of short duration (one to two years) if proper management procedures were applied. These included leaving buffer strips along water courses, minimizing soil compaction by heavy equipment, and prompt revegetation of deforested areas. The presence of wetland areas on the North Fork of

Flint Creek will help to reduce suspended sediment in the stream below them. Timber harvest from private land has been minimal, however, there is no guarantee that situation will not change. Logging activity per se on private property is regulated under the following state statutes:

75-2-211, 7-33-2205, 76-13-121, administered by Department of State Lands, concerning burning permits;

76-13-502, Department of State Lands, concerning operation of portable sawmills;

7-8-2608,2609, Department of State Lands, concerning timber harvest;

77-5-211,212,213, Department of State Lands, concerning timber harvest and slash disposal.

Potential impacts from mining are associated with road construction, transportation, surface disturbance during the mining process, mine waste-water discharge, and leaching from mine spoils. Hardrock mining operations are regulated by Statue 82-4-301, MCA, and Rule 26.4.101, ARM, administered by Department of State Lands. A reclamation and revegetation bond is required of mining companies unless a small miners exemption applies, in which case the operator must agree not to pollute streams. Hard rock mining permits may be denied if the operational plan does not comply with the Montana Clean Air Act, Montana Water Quality Act, or the Public Water Supply Act. Relative to mining operations, plans and specifications for tailing ponds, leach pads, and holding facilities must be submitted to the

Water Quality Bureau for review and approval at least 180 days prior to commencing operations.

Construction in or disturbance of stream beds, banks, or wetland areas is regulated by the Streambed and Land Preservation Act (75-7-101, MCA) and the Rivers and Harbors Act (33 USC, 401 et seq.) Regulations are administered by the local Board of County Commissioners, Conservation District Supervisors, the Montana Department of Fish, Wildlife and Parks, and the Army Corps of Engineers. Notice must be given to the Department of Fish, Wildlife and Parks of all public or private construction or disturbance of streambeds, stream banks, and wetland areas for permit review. The purpose of this procedure is to minimize soil erosion and siltation to streams, after considering needs of agriculture and other beneficial uses of water.

Results of the Septic Leachate Survey and Dye Study indicate that septic tanks are not significantly impacting water quality at this time, nor are they responsible for the increased growth of aquatic weeds. Continued efforts to maintain properly functioning systems and upgrade below standard systems, coupled with proper planning of additional development to minimize construction near the shoreline, should provide continued protection for water quality in the future. Using Environmental Protection Agency guidelines developed during the National Eutrophication Survey, inputs of phosphorus from shoreline septic systems were estimated at less than 6 percent of the total estimated phosphorus input to the reservoir.

In the absence of extensive agricultural land use near the reservoir, the relatively low annual rainfall, and the natural condition of the vegetative cover, it is not anticipated that direct runoff would be a significantly manageable source of nitrogen or phosphorus input to the reservoir. Vegetative cover on most residential sites has remained in a relatively natural state. Many homeowners do not cultivate lawns and have kept most of their trees and native grasses, which minimizes increases in direct surface runoff. The maintenance of an intact shoreline "buffer zone" of natural vegetation is also minimizing inputs due to direct surface runoff from many residential or high use recreational areas. Exceptions occur where runoff is channeled onto roads and roadside drainage ditches. This is noticeable at Edwards' Subdivision, near the Anaconda campgrounds on the north side of Jericho Bay, and below Shakopee Heights. Although the magnitude of these inputs is not great, they probably constitute the largest volume of silt entering the reservoir.

Subdivision and other residential development in Montana is controlled under the Montana Subdivision Law, which requires that developers submit preliminary designs to local and state agencies for review and approval. Since 1973, land could not be sold in parcels of less than 20 acres without prior lifting of sanitary restriction and or review by planning boards, which insures that public health will be protected. Subdivision approval require thorough review of local conditions pertinent to sewage disposal. That the subdivision review requirements are adequate to protect environmental quality is demonstrated by the recent Wanigan planned development, near Big Fork on Flathead Lake. During the review process, opportunities are provided for public input during public hearings held by the local planning board. The Montana Model Subdivision Regulations provide guidelines for future subdivision development under the Planned Unit Development concept, which clusters construction to minimize surface disturbance, and maximizes open space and retention of natural areas. The Planned Unit Development concept offers the greatest potential to realize the benefits of economic development while still minimizing negative impacts on esthetics and the environment.

SLAG ANALYSIS AND IMPACT ON WATER QUALITY

Background

Reverb or smelting slag, a byproduct of the operation of the metal smelter formerly operated by Anaconda Minerals Company in Anaconda, Montana, is used by Deer Lodge County to "sand" roads in Deer Lodge County, including U. S. Highway 10A, which parallels the shoreline of Georgetown Lake for some distance, and Denton's Point Road, which crosses Stewart Mill Creek about 100 meters upstream from its entry into the reservoir. Possible pathways of contamination of aquatic environments include leaching of soluble components from the slag by precipitation and runoff, and washing of slag into the reservoir by runoff, where exposure to reducing conditions or bacterial action in the sediment could result in mobilization of toxic compounds and incorporation into the food chain. Windrows of slag occur along the highway adjacent to the reservoir and piles of the material accumulate due to continual plowing and sanding of the roads during the winter.

Prior analysis (Appendix 9 EPA, 1980, unpublished data: Appendix 10; Anaconda Company, 1974-79, unpublished data) of the smelting slag from the Anaconda Company reduction works in Anaconda indicated that this material contains substantial amounts of elements potentially hazardous to the environment or human health. EPA analyses were based on extraction in distilled water at a concentration of 5 g slag/50 ml water, representing a slag loading rate of approximately 10% by mass. Extractions were carried out for 30 days at a pH of approximately 6.8 and ambient temperature. Resulting concentrations in leachates are given in Table 48.

At the experimental loading rate, equivalent to 484 kg/m^2 (approximately 1000 lb/square yard) in Georgetown Lake, concentrations of metals in leachates exceeded EPA criteria for protection of aquatic life for cadmium, arsenic, copper, lead and chromium.

Table 48. Concentrations of heavy metals in slag leachates (EPA, unpublished data, 1980). EPA criteria for protection of aquatic life calculated based on minimum hardnenss of 75 mg/l $CaCO_3$.

Sample	Cd	As	Cu	Pb	Cr	Hg	Zn	Ag
1	3.4	70	320	290	69	<0.01	62	1
2	3.2	90	210	190	22	<0.01	60	1
3	2.1	64	540	140	4	<0.01	57	4.6
Mean	2.9	75	360	210	32	<0.01	60	3.3
EPA Criteria								
Drinking water	10	50	1000	50	50	0.144	5000	---
Aquatic life								
maximum	2.2	440	17	120	21	4.1	253	---
24 hour ave	0.02	40	5.6	2.0	0.29	0.02	47	---

Results

Analysis of Surface and Ground Water

Results of water analysis are shown in Table 49. EPA criteria for water quality for elements of interest and the minimum limits of analytical detection are shown in Table 50. Cadmium (Cd), arsenic (As), copper (Cu), cobalt (Co), lead (Pb), chromium (Cr), silver (Ag), mercury (Hg), and zinc (Zn) were analyzed.

The EPA recommends concentration limits for cadmium of 10 ug/l for drinking water, 0.02 ug/l 24-hour average concentration for the protection of aquatic life, and 2.2 ug/l maximum short-term concentration for protection of aquatic life. The detection limit for cadmium with the method of analysis was 2 ug/l. Concentrations in lake, stream, and groundwater samples were all near or at detectable limits, with the exception of the sample from Flint Creek below the dam (8ug/l). This value is above EPA criteria for protection of aquatic life, and may indicate loading of cadmium in the reservoir, although the source cannot be determined. Data collected on the North Fork of Flint Creek upstream from the reservoir have been previously reported as containing <1 ug/l cadmium (Ingman and Bahls, 1979).

The EPA recommends concentration limits for arsenic of 0.02 ug/l for drinking water, 40 ug/l 24-hour average concentration for the protection of aquatic life, and 440 ug/l maximum short-term concentration for the protection of aquatic life. Arsenic concentrations in all samples were below levels recommended for the protection of aquatic life, but in several cases exceeded the recommended criteria for

TABLE 49. Results of chemical analyses of water samples for potentially toxic elements in Anaconda smelting slag.

	CONCENTRATION, ug/l										
	Cd	As	Cu	Co	Pb	Cr	Ag	Hg	Zn	Se	Mn
Analytical Detection limit	2	0.1	2	10	40	2	2	.04	4	.10	2
Sample											
1	2	2.3	5.0	20	<40	5.0	<2	0.23	12	—	—
2	3	2.8	<2	<10	<40	3	<2	1.2	<4	—	—
3	4	2.6	5.0	20	<40	2	<2	<.04	<4	—	—
4	<2	1.3	4.0	30	<40	2	<2	0.06	6	—	—
5	4	0.90	9	20	<40	6	<2	0.10	<4	—	—
6	8	3.2	7	20	<40	3	<2	0.10	<4	—	—
7	<2	1.2	<2	10	<40	3	<2	0.06	<4	—	—
8	<2	0.70	—	10	<40	—	—	0.10	6	—	—
9	<2	15	86	—	<40	6	—	0.44	—	0.11	16

Samples 1,2,and 3 are lake water samples from the area immediately adjacent to Highway 10A; samples 4 and 5 are ground water samples springs emerging in gravels adjacent to the shoreline along the highway; sample 6 is the outflow below the power house; 7 is North Fork Flint Creek; 8 is Stewart Mill Creek; 9 is snowmelt from Highway 10A.

Table 50. EPA water quality criteria for toxic elements of interest in Anaconda smelting slag. Concentrations (ug/l) calculated according to EPA, 1980(a-f), based on hardness = 75 mg/l $CaCO_3$ (minimum).

	Element (ug/l)					
Criteria	As	Cu	Cd	Hg	Pb	Zn
Protection of aquatic life						
24-hour·average	40	6	0.02	0.20	2	47
Short-term maximum	440	17	2.2	4.1	120	253
Protection of Human Health						
Drinking	0.02	1000	10	0.14	50	5000
Consumption of fish	0.18	----	--	0.14	50	5000

human health (both drinking water and fish consumption). The EPA recommends concentration limits for copper of 1.0 mg/l for drinking water, 5.6 ug/l 24-hour average for the protection of aquatic life, and 17 ug/l short-term maximum concentration for the protection of aquatic life. Natural copper concentrations for water in the area appear to be about 3-9 ug/l as indicated by analyses of groundwater and stream samples. Lake water samples were within this range of values, the highest being 7ug/l, the lowest being at the limit of analytical detection, 2 ug/l.

No recommended concentration limits for cobalt were found in "Quality Criteria for Water" (EPA, 1976). Analytical values for lake water samples were in the same range as those obtained for stream and groundwater samples, 10-30 ug/l.

The EPA recommends concentration limits for lead of 50 ug/l for human health (drinking water), 40 ug/l for human health (fish consumption), 2 ug/l 24-hour average concentration for the protection of aquatic life, and 120 ug/l maximum short-term concentration for the protection of aquatic life. Lead concentrations in all samples were below the limit of analytical detection, 40 ug/l.

Recommended concentration limits for chromium are 50 ug/l for drinking water and 3.8 ug/l average concentration for protection of aquatic life. Analytical concentrations of chromium in all samples was in the range of 2-6 ug/l. Lake water samples were within the range of stream and groundwater samples. The highest value obtained, 6 ug/l, was for groundwater.

Analytical concentrations of silver were below the limits of analytical detection, 2 ug/l, in all samples.

The EPA recommends concentration limits for mercury of 0.14 ug/l for human health (drinking water and fish consumption), 0.20 ug/l 24-hour average concentration for the protection of aquatic life, and 4.1 ug/l maximum short-term concentration for protection of aquatic life. Analytical concentrations of mercury ranged from below detectable limits, 0.04 ug/l, to 1.2 ug/l. Background levels as indicated by stream and groundwater samples, are in the range of 0.06-0.10 ug/l total mercury. Highest concentrations, 0.23 and 1.20 ug/l, were found in lake water samples collected near highway 10A (locations 1 and 2). The third lake water sample contained a mercury concentration below the analytical limit of detection. The dam outflow concentration was 0.10 ug/l.

The EPA recommends concentrations for zinc of 5 mg/l for human health, 47 ug/l maximum 24-hour average for protection of aquatic life, and 253 ug/l maximum short-term concentration for the protection of aquatic life. Analytical concentrations of zinc in streams and groundwater samples were from 4-6 ug/l. Lake water samples contained from below detectable limits (4 ug/l) to 12 ug/l total zinc. The dam outflow contained less than 4ug/l zinc.

Analysis of Snowmelt

The results are shown in Table 49 . Significantly elevated levels were obtained for copper (86 ug/l), arsenic (15 ug/l), and mercury (0.44 ug/l). These results indicate that roadside slag accumulations may be capable of introducing some environmentally hazardous compounds into the reservoir. Mercury and arsenic are of particular concern.

Leachates from Slag and Sediment into Lake Water

Experimental results are summarized in Tables 51 and 52. Linear regressions were run on sample results where it appeared any loading-concentration relationship existed. Some enrichment of all analysed metals occurred in the slag leachates. Only one sample, S2, loading 3 g/150 ml, showed enrichment of mercury, 1.3 ug/l analytical concentration. This equals a mercury loading rate potential of 65 ug/kg of slag. Assuming that one kg (2.2 pounds) of slag was spread on a square meter of sediment surface, covered by water 4 meters deep, which approximates the minimum mean depth which might be obtained under drawdown conditions, this represents an average concentration of 0.016 ug/l mercury for the water column (EPA standard is 0.20 ug/l for protection of aquatic life and 0.14 ug/l for protection of human health relative to consumption of fish or other aquatic organisms). The other two slag samples showed levels of mercury below the controls. Significant enrichment of cadmium, chromium, and lead occurred in one slag sample at the lowest loading rate, indicating the possibility of contamination for these elements. Significant enrichment of zinc occurred in all slag samples. The linear regression of zinc concentration on loading rate showed an r-value of 0.986, or almost a straight line relationship, indicating that zinc is quantitatively released by slag under the experimental conditions.

Copper concentrations also showed a linear relationship to loading rate (r = 0.967). Using the regressions obtained for zinc and copper, the loading potential of zinc is 108 mg/kg; that of copper is 995 mg/kg. Using the EPA criteria for protection of aquatic life for copper of 5.6 ug/l 24-hour average concentration, a slag-loading rate of 27 g/m^2 (0.054 lb/square yard) would be sufficient to cause the maximum recommended concentration. The slag loading rate required to cause maximum recommended concentrations for zinc would be 2.1 kg/m^2 (4.2 lb/square yard). In the sediment exchange experiment, only mercury and chromium showed any enrichment over the controls. Chromium was enhanced in only one of the three sediment treatments, 10 ug/l at the intermediate loading rate. Other samples showed a chromium concentration equal to the controls. Mercury showed a high negative correlation, r = -0.834, to loading rate, indicating perhaps that mercury was being released by one mechanism, then re-adsorbed onto sediment by another, slower, mechanism. The maximum concentration of mercury obtained was 1.9 ug/l, equivalent to a mercury loading rate of 52 ug/kg sediment, which corresponds to a mercury concentration of 0.13 ug/l per square meter of sediment in water 4 m deep. This result is ameliorated by the apparent re-absorption of mercury by larger amounts of sediment. Whether this is due to a combination of microbial intermediation and subsequent adsorption cannot be determined. The result of sediment experiments are inconclusive relative to actual dynamics of mercury in situ, but indicate no problems with other analysed metals.

TABLE 51. Concentrations of metals in slag/sediment leachates.

	LOADING	CONCENTRATION ug/l					
SAMPLE	g/l	Hg	Cd	Zn	Cr	Pb	Cu
C1	0/0	0.13	2	16	<2	<40	5
C2	0/0	0.60	2	13	<2	40	10
S1	1.0	<0.04	25	37	29	470	12
S2	3.0	1.3	3	190	2	50	110
S3	5.0	<.04	3	470	2	<40	400
M1	0.55	1.90	<2	7	<2	50	8
M2	1.95	0.35	<2	16	10	<40	<2
M3	4.26	<.04	<2	<4	<2	<40	8

C = Control; S = Slag; M = Sediment. Loading given in dry weight.
1 mg/l = 1000 ug.
Linear regressions:
Slag; Zn r = 0.986, s = 0.108, i = -0.1064
Cu r = 0.967, s = 0.997, i = -1.287
Sediment; Hg r = -0.834, s = -0.178, i = -1.287

TABLE 52. Chemical parameters for slag/sediment leachates.

SAMPLE	INITIAL pH	FINAL pH	D. O.
C1	5.6	6.5	3.0
C2	5.2	6.5	3.2
S1	5.2	6.1	1.3
S2	5.2	6.1	2.6
S3	5.2	5.9	1.5
M1	5.6	6.8	1.2
M2	5.6	6.9	0.8
M3	5.6	6.8	1.9

DISSOLVED OXYGEN MEASURED AT TERMINATION OF INCUBATION.

Fish Tissue Analysis

Results are shown in Table 53. The size of the fish sampled ranged from 24 to 37 cm (9-15 inches). Concentrations of metals assayed are all well below recommended limits for human consumption. There was no apparent relationship between concentration and total length of fish. Average concentration for mercury in all fish was 0.054 ug/g tissue. USFDA recommends a limit of 1.0 ug/g tissue, 20 times greater than the concentrations obtained. The average concentration of arsenic was 0.029 ug/g tissue; recommennded limits for arsenic in food for human consumption are about 5 ug/g, about 160 times greater than concentrations of arsenic in fish samples. The average concentrations of cadmium and lead were below analytical detection limits. Of the metals considered, mercury has the highest potential for concentration in aquatic organisms (Phillips, undated). Arsenic does not have a high potential for biomagnification (EPA, 1976).

TABLE 53. Concentrations of toxic substances in muscle tissue of rainbow and brook trout from Georgetown Lake.

	CONCENTRATION ug/g			ALLOWABLE CONCENTRATION ug/g
ELEMENT	AVE	MIN	MAX	
Arsenic	0.029	0.010	0.050	5.0
Mercury	0.054	0.034	0.075	0.50
Cadmium	<0.100*			13
Lead	<0.100*			**

Allowable concentration for Arsenic in fruit; no criteria established for fish.

*Below limit of detection.

**No criteria established for fish.

Analysis of Plants for Toxic Elements

The laboratory report is included as Appendix 11. Analytical results are given in Table 54. Samples 1 and 4 are Potamogeton praelongus stems and leaves from near Highway 10A and Phillipsburg Bay, respectively. Samples 2 and 3 are a mixture of Elodea, Myriophyllum, and Chara from near Highway 10A. Samples 5 and 6 are of similar composition as 2 and 3, taken from Phillipsburg Bay and Stewart Mill Bay, respectively.

Arsenic concentrations in samples 2, 3, 5, and 6 are above normal background levels (0.05-1.0 ug/g) found in natural terrestrial (Munshower, et al; 1977) and aquatic vegetation (EPA, 1976). The higher concentrations of arsenic found in samples 2, 3, 5, and 6 indicate that most of the arsenic detected may be associated with the sediment, which was present in those samples as a contaminant, rather than the plant tissue. Samples 1 and 4 had very little or no sediment present, therefore represent more accurately the arsenic concentrations likely to be present in plant tissues themselves.

Reported cases of arsenic poisoning of livestock have been attributed to ingestion of mud and soil, rather than forage, with arsenic concentrations of 3-9 ug/g (Grimmet, 1939). The levels of arsenic (1-3 ug/g) found in samples 1 and 3, composed of P. praelongus are not above levels (3-100 ug/g) occurring in aquatic plants (algae) from a variety of environments (EPA, 1976). Further confirmation on the possible effects of the observed levels of arsenic on livestock should be obtained.

Table 54. Analyses of toxic elements in plants from Georgetown lake.

Sample	As	Se	Cd	Cu	Zn	Hg
1	2.2	0.06	0.13	3.8	7.4	<0.02
2	17	0.11	0.49	12	27	<0.02
3	17	0.12	0.58	15	22	<0.02
4	1.7	0.11	0.23	7.8	17	<0.02
5	26	0.12	0.43	14	22	<0.02
6	20	0.15	0.70	14	21	<0.02
Average	14	0.11	0.43	11.1	19.4	<0.02
minimum	1.7	0.06	0.13	3.8	7.4	<0.02
maximum	26	0.15	0.70	15	27	<0.02

Samples 1 and 4 are Potamogeton praelongus stems and leaves collected near Highway 10 A and in Philipsburg Bay, respectively.
Samples 2 and 3 are a mixture of Elodea, Myriophyllum, andChara, collected near Highway 10A.
Samples 5 and 6 are of similar composition to 2 and 3, collected from Philipsburg Bay and Stewart Mill Bay, respectively.

The levels of arsenic found in the remaining samples (17-26 ug/g) could easily prove toxic to livestock. The presence of sediment as a contaminant contributes to the high levels of arsenic found. The levels of arsenic observed prohibit the use of aquatic sediments or dried plants from Georgetown Lake as mulch or fill for domestic gardens or agricultural crop areas, but are satisfactory for use as fill or mulch for lawns or other planted areas not cultivated for food production. In comparison, surface soils in the Deer Lodge Valley contain from 2.5-50 ug/g arsenic (Munshower, 1972).

Cadmium is slightly higher than background levels found in eastern Montana range plants (0.02-0.2 ug/g). The highest concentrations were found in samples 2, 3, 5, and 6, in which sediment was present. Concentrations in samples 1 and 4 were at background levels.

Copper was slightly higher (ave. 9.4 ug/g) than background (5-6 ug/g). The highest concentrations were found in samples 2, 3, 5, and 6. Samples 1 and 4 contained background levels. The other elements analysed were present at background levels comparable to terrestrial vegetation from other areas of the state.

The consistently higher concentrations of arsenic, cadmium, and copper in samples 2,3,5, and 6, which contained some sedimentary material, indicates that these elements may be present in the sediments in higher than normal concentrations. The source is speculation. The Anaconda smelting slag represents one possible source of the observed contaminants. Arsenic and cadmium, major volatile emissions from the smelting of copper, are also known to be present in high concentrations in soils of the Deer Lodge Valley, presumably from the Anaconda copper smelter (Personal Communication, Dennis Neuman, Department of Plant and Soil Science, Montana State University, Bozeman, Montana). In addition to the slag, it is possible that the levels in Georgetown Lake are due to atmospheric transport and precipitation of arsenic, cadmium, and copper. Another possible source is from the many small mines that were formerly active in this area (Ingman and Bahls, 1979). It is also possible that the source is geological, as Georgetown Lake essentially forms a large settling basin for a drainage of about 33000 acres, and was known to be a marshy area before the impoundment was formed.

Discussion

There does not appear to be a danger to human health from the observed contaminants through the consumption of fish from Georgetown Lake. The low concentrations of analyzed contaminants in fish samples from Georgetown Lake indicate this to be true. However, dried aquatic vegetation or dredged lake sediment should not be used as mulch for gardens, agricultural cropland, or pastureland which will receive intensive grazing.

The possible contaminants are highly insoluble under oxygenated conditions. However, the concentrations recommended for some contaminants by present EPA criteria documents, particularly cadmium, arsenic, and mercury, are sufficiently low to be attained under certain conditions present in the reservoir at some times of the year. The extremely low concentrations of mercury which can be detected under present analytical techniques make sample contamination a problem and a possibility in the present study. There is no way to quantify the effects of extremely low-level concentrations of these elements on the aquatic biota, particularly in regard to growth and reproduction. It has been demonstrated that mercury is capable of having a negative effect on reproduction and growth of fish at concentrations near those obtained in some of the water samples collected near the highway. However, the high rates of fish growth and reproduction attained in Georgetown Lake (Personal communication, Jim Vashro, MDFWP) suggest that effects of mercury on the aquatic environment are minimal or non-existent, and that most of the mercury present probably exists as inorganic mercury, which is relatively low in toxicity compared to organic forms (Phillips, undated).

Cadmium is a highly toxic heavy metal to aquatic organisms at very low concentrations. Toxic concentrations are approached or surpassed by the analytical values obtained. It is highly unlikely that the concentrations are indicative of the concentrations of cadmium in water strata further removed from the sediment with higher concentrations of dissolved oxygen, as cadmium is only slightly soluble under oxygenated conditions. It has also been demonstrated that copper and zinc are capable of negatively effecting fish growth and reproduction at concentrations which might be attained in Georgetown Lake due to slag loading.

Recommendations

Due to the association of mercury with water exposed to slag, the presence of elevated cadmium concentrations, and the mobility of zinc and copper out of the slag into lake water in the leaching experiment, it is recommended that the slag not be used to sand roads within one-quarter mile of Georgetown Lake or 100 yards of bridges over running streams which drain into Georgetown Lake. It is also recommended that the monitoring program include collection of water samples from the area adjacent to Highway 10A, other control areas in the reservoir, and the outflow to verify observed levels of the metals mercury and cadmium. Samples should be collected in mid-winter, early spring while ice cover is still on, and late summer to cover a variety of chemical and biological conditions. If dredging projects are undertaken, it is recommended that dredge spoils not be applied to agricultural areas or domestic gardens. If a harvesting project is implemented, plant material should not be used as mulch for domestic gardens or agricultural areas, for human consumption, or as feed for livestock.

The survey on slag contamination which was done under the Georgetown Lake Clean Lakes Project was not intended to be an exhaustive or conclusive investigation. The environmental chemistry of Anaconda smelting slag in aquatic and terrestrial communities exposed to the material should be investigated more thoroughly to determine the potential for environmental contamination.

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APPENDICES

CLEAN LAKES QUESTIONNAIRE

Appendix 1

1. Resident of: __Deer Lodge; __Anaconda; __Philipsburg; __Butte; __Georgetown Lake area; ___Missoula; __Montana; __Other.

2. Own property in Georgetown Lake area? __Yes __No

3. Please rank your recreational uses of the Georgetown Lake area in order of their importance by placing 1,2,3, etc. in the boxes below. Do not put a number beside an activity you don't participate in: __fishing; __waterfowl hunting; __boating/water skiing; __swimming/diving; __camping; __snowmobiling; __Other (hiking, cross country skiing, etc.)

4. Do you feel access to the Georgetown Lake shoreline is adequate? __Yes __No

5. Anaconda Company owns 60% of the shoreline of Georgetown Lake. Would you favor public acquisition of some of this property for recreational use if it becomes available for purchase or trade? __Yes __No

6. Are more campsites needed around the lake __; picnic areas __; boat ramps__; swimming areas ___.

7. Do the numbers of people now using the reservoir interfere with your enjoyment of: __fishing; __boating; __camping; __hiking; __skiing; __snowmobiling; __other.

8. Do the weed growths in Georgetown Lake interfere with your enjoyment of: fishing __; boating__; water skiing __; other __.

9. Does the present density of homes around the lake detract from your enjoyment of recreation on Georgetown Lake? __yes __no.

10. Would you object to further development of homesites or commercial interests in the Georgetown Lake area, if these did not cause a deterioration in the chemical or biological condition of the lake? ___yes ____no.

11. Would you favor restriction of commercial development in the Georgetown Lake area for any of the following reasons: (1) protection of fishing quality__; (2) protection of esthetic values (scenery, solitude, quiet, etc.) __; (3) protection of water quality (public health, prevention of eutrophication)___.

12. Do you feel adequate commercial services are available on Georgetown Lake? Boat rental__yes __no; boat docks __yes __no; restaurants/bars __yes __no; motels __yes __no.

13. Do you think the use of the black sanding material used on the road in winter is objectional because of its appearance? __yes __no.

14. Would you favor the use of another material at greater expense to improve appearance of the roadside area? ___yes ___no.

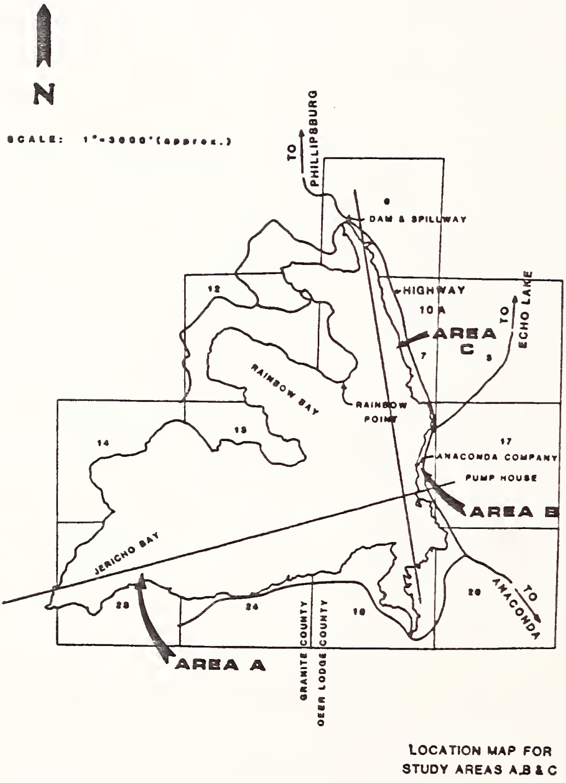
15. Would you favor the use of another material for road sanding material if the black sand were found to be causing the presence of harmful substances in water, fish, or plants? ___yes ___no.

16. Would you support formation of a special management district similar to the State Conservation Districts to administer a weed management program for Georgetown Lake? ___yes ___no ___don't know.

17. If a special weed management program were established for Georgetown Lake which required local funding, would you favor: (1) a daily special use fee____; (2) an annual special use fee___; (3) creation of a Special Improvement District ___; (4) a revenue program employing all of the above ____; (5) do not favor any fee structure ____.

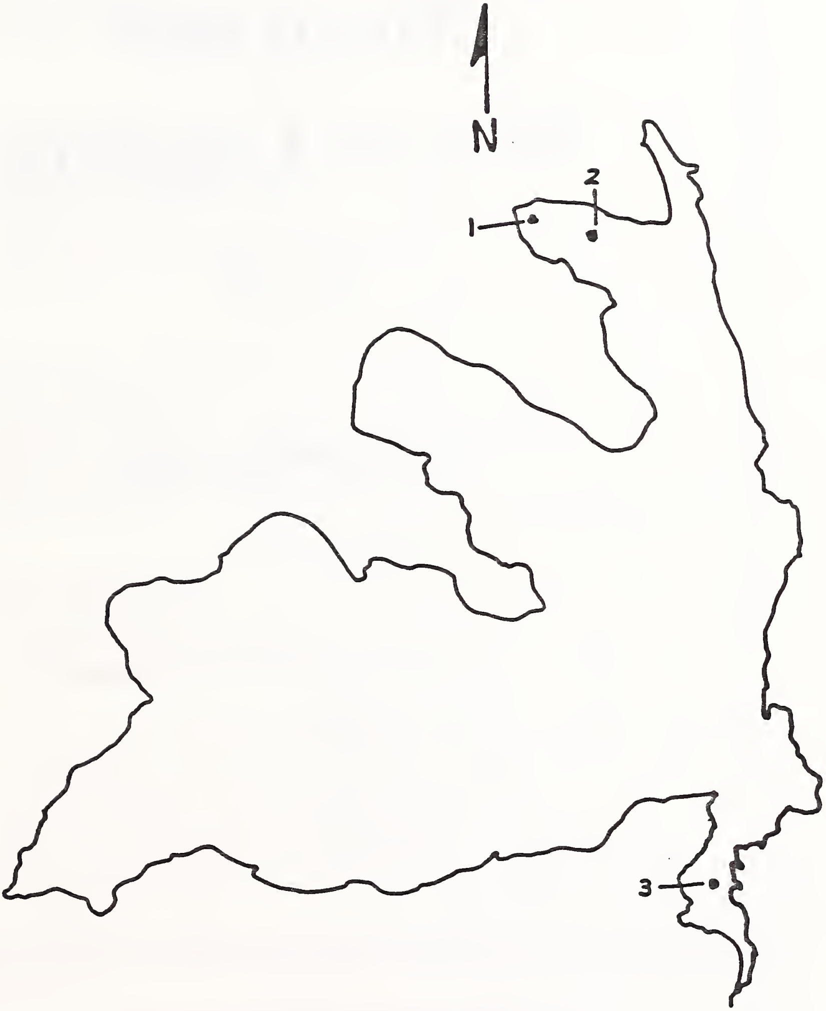
18. Do you think that a weed management program will benefit landowners through: (1) increased property values __yes __no ___undecided; (2) improved recreational opportunities ___yes ___no ___undecided.

APPENDIX 2: Flight lines for aerial photography of macrophytes



. Location of study areas for remote sensing of *P. praelongus* canopy coverage, 1975-1981.

Time of Flight: 0845-1000
Lens: 50 mm
Aircraft elevation: 9660 ft
Film: Ektachrome
Flight lines as shown on Fig.
50% endlap on frames
Tie coverage to shoreline in areas A, B, and C



APPENDIX 3.

MONITORING PROGRAM: MACROPHYTE SAMPLING SITES

1 - Phillipsburg Bay; depth 1.8-2.2 m; community type - Elodea
2 - Phillipsburg Bay; depth 3.8-4.5 m; community type - big leaf pondweed
3 - Stewart Mill Bay; depth 1.8-2.2 m; community type - Myriophyllum (milfoil)

Montana
Water Quality
Act

(Includes 1979 revisions)

APPENDIX 4.

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Part 1

General Provisions

75-5-101. Policy. It is the public policy of this state to:

(1) conserve water by protecting, maintaining, and improving the quality and potability of water for public water supplies, wildlife, fish and aquatic life, agriculture, industry, recreation, and other beneficial uses;

(2) provide a comprehensive program for the prevention, abatement, and control of water pollution.

History: En. Sec. 121, Ch. 197, L. 1967; amd. Sec. 1, Ch. 21, L. 1971; amd. Sec. 1, Ch. 455, L. 1975; R.C.M. 1947, 69-4801(1).

75-5-102. Purpose — rights of action not abridged. (1) A purpose of this chapter is to provide additional and cumulative remedies to prevent, abate, and control the pollution of state waters.

(2) This chapter does not abridge or alter rights of action or remedies in equity or under the common law or statutory law, criminal or civil, nor does this chapter or an act done under it estop the state or a municipality or person, as owner of water rights or otherwise, in the exercise of his rights in equity or under the common law or statutory law to suppress nuisances or to abate pollution.

History: En. Sec. 17, Ch. 21, L. 1971; amd. Sec. 6, Ch. 506, L. 1973; amd. Sec. 67, Ch. 349, L. 1974; amd. Sec. 11, Ch. 455, L. 1975; R.C.M. 1947, 69-4823(4).

75-5-103. Definitions. Unless the context requires otherwise, in this chapter the following definitions apply:

(1) "Sewage" means water-carried waste products from residences, public buildings, institutions, or other buildings, including discharge from human beings or animals, together with groundwater infiltration and surface water present.

(2) "Industrial waste" means any waste substance from the process of business or industry or from the development of any natural resource, together with any sewage that may be present.

(3) "Other wastes" means garbage, municipal refuse, decayed wood, sawdust, shavings, bark, lime, sand, ashes, offal, night soil, oil, grease, tar, heat, chemicals, dead animals, sediment, wrecked or discarded equipment, radioactive materials, solid waste, and all other substances that may pollute state waters.

(4) "Contamination" means impairment of the quality of state waters by sewage, industrial wastes, or other wastes, creating a hazard to human health.

(5) "Pollution" means contamination or other alteration of the physical, chemical, or biological properties of any state waters which exceeds that permitted by Montana water quality standards, including but not limited to standards relating

to change in temperature, taste, color, turbidity, or odor; or the discharge, seepage, drainage, infiltration, or flow of any liquid, gaseous, solid, radioactive, or other substance into any state water which will or is likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife. A discharge, seepage, drainage, infiltration or flow which is authorized under the pollution discharge permit rules of the board is not pollution under this chapter.

(6) "Sewage system" means a device for collecting or conducting sewage, industrial wastes, or other wastes to an ultimate disposal point.

(7) "Treatment works" means works installed for treating or holding sewage, industrial wastes, or other wastes.

(8) "Disposal system" means a system for disposing of sewage, industrial, or other wastes and includes sewage systems and treatment works.

(9) "State waters" means any body of water, irrigation system, or drainage system, either surface or underground; however, this subsection does not apply to irrigation waters where the waters are used up within the irrigation system and the waters are not returned to any other state waters.

(10) "Person" means the state, a political subdivision of the state, institution, firm, corporation, partnership, individual, or other entity and includes persons resident in Canada.

(11) "Council" means the water pollution control advisory council provided for in 2-15-2107.

(12) "Board" means the board of health and environmental sciences provided for in 2-15-2104.

(13) "Department" means the department of health and environmental sciences provided for in Title 2, chapter 15, part 21.

(14) "Local department of health" means the staff, including health officers, employed by a county, city, city-county, or district board of health.

(15) "Point source" means any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, or vessel or other floating craft, from which pollutants are or may be discharged.

(16) "Owner or operator" means any person who owns, leases, operates, controls, or supervises a point source.

(17) "Standard of performance" means a standard adopted by the board for the control of the discharge of pollutants which reflects the greatest degree of effluent reduction achievable through application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants.

(18) "Effluent standard" means any restriction or prohibition on quantities, rates, and concentrations of chemical, physical, biological, and other constituents which are discharged into state waters.

History: En. Sec. 122, Ch. 197, L. 1967; amd. Sec. 2, Ch. 21, L. 1971; amd. Sec. 1, Ch. 506, L. 1973; amd. Sec. 59, Ch. 349, L. 1974; amd. Sec. 2, Ch. 455, L. 1975; amd. Sec. 3, Ch. 308, L. 1977; amd. Sec. 1, Ch. 444, L. 1977; R.C.M. 1947, 69-4802.

75-5-104. Special applicability. This chapter applies to drainage or seepage from all sources, including that from artificial, privately owned ponds or lagoons, if such drainage or seepage may reach other state waters in a condition which may pollute the other state waters.

History: En. Sec. 124, Ch. 197, L. 1967; amd. Sec. 3, Ch. 21, L. 1971; R.C.M. 1947, 69-4804.

75-5-105. Confidentiality of records. Any information concerning sources of pollution which is furnished to the board or department or which is obtained by either of them is a matter of public record and open to public use. However, any information unique to the owner or operator of a source of pollution which would, if disclosed, reveal methods or processes entitled to protection as trade secrets shall be maintained as confidential if so determined by a court of competent jurisdiction. The owner or operator shall file a declaratory judgment action to establish the existence of a trade secret if he wishes such information to enjoy confidential status. The department shall be served in any such action and may intervene as a party therein. Any information not intended to be public when submitted to the board or department shall be submitted in writing and clearly marked as confidential. The data describing physical and chemical characteristics of a waste discharged to state waters shall not be considered confidential. The board may use any information in compiling or publishing analyses or summaries relating to water pollution if such analyses or summaries do not identify any owner or operator of a source of pollution or reveal any information which is otherwise made confidential by this section.

History· En. Sec. 16, Ch. 21, L. 1971; amd. Sec. 10, Ch. 455, L. 1975; R.C.M. 1947, 69-4822.

75-5-106. Interagency cooperation. The council, board, and department may require the use of records of all state agencies and may seek the assistance of such agencies. State, county, and municipal officers and employees, including sanitarians and other employees of local departments of health, shall cooperate with the council, board, and department in furthering the purposes of this chapter, so far as is practicable and consistent with their other duties.

History: En. Sec. 21, Ch. 21, L. 1971; R.C.M. 1947, 69-4827.

Part 2

Administrative Agencies

75-5-201. Board rules authorized. The board shall adopt rules for the administration of this chapter.

History: En. Sec. 6, Ch. 21, L. 1971; amd. Sec. 2, Ch. 506, L. 1973; amd. Sec. 62, Ch. 349, L. 1974; amd. Sec. 5, Ch. 455, L. 1975; amd. Sec. 3, Ch. 444, L. 1977; R.C.M. 1947, 69-4808.2(1)(g).

75-5-202. Board hearings. The board shall hold hearings necessary for the proper administration of this chapter or, in the case of permit issuance hearings, delegate this function to the department.

History: En. Sec. 6, Ch. 21, L. 1971; amd. Sec. 2, Ch. 506, L. 1973; amd. Sec. 62, Ch. 349, L. 1974; amd. Sec. 5, Ch. 455, L. 1975; amd. Sec. 3, Ch. 444, L. 1977; R.C.M. 1947, 69-4808.2(1)(f).

75-5-203 through 75-5-210 reserved.

75-5-211. Department to administer chapter. (1) Except as otherwise provided, the department is responsible for administration of this chapter.

(2) The department may use its personnel and those of the local departments of health as necessary to administer this chapter.

History: En. Sec. 125, Ch. 197, L. 1967; amd. Sec. 4, Ch. 21, L. 1971; amd. Sec. 60, Ch. 349, L. 1974; R.C.M. 1947, 69-4805.

75-5-212. Department research and information. The department shall:
(1) collect and furnish information relating to the prevention and control of water pollution;
(2) conduct or encourage necessary research and demonstrations concerning water pollution.

History: En. Sec. 7, Ch. 21, L. 1971; amd. Sec. 3, Ch. 506, L. 1973; amd. Sec. 63, Ch. 349, L. 1974; amd. Sec. 6, Ch. 455, L. 1975; amd. Sec. 4, Ch. 444, L. 1977; R.C.M. 1947, 69-4809.1(1)(d), (1)(e).

75-5-213. Comprehensive plan for prevention and control of water pollution. The department shall advise, consult, and cooperate with other states, other state and federal agencies, affected groups, political subdivisions, and industries in the formulation of a comprehensive plan to prevent and control pollution.

History: En. Sec. 7, Ch. 21, L. 1971; amd. Sec. 3, Ch. 506, L. 1973; amd. Sec. 63, Ch. 349, L. 1974; amd. Sec. 6, Ch. 455, L. 1975; amd. Sec. 4, Ch. 444, L. 1977; R.C.M. 1947, 69-4809.1(1)(h).

75-5-214 through 75-5-220 reserved.

75-5-221. Water pollution control advisory council — general. (1) The council provided for in 2-15-2107 shall select a chairman from among its members. The director of health and environmental sciences shall designate a member of the staff of the department to act as secretary to the council. The secretary shall keep records of all actions taken by the council.
(2) It shall hold at least two regular meetings each calendar year. Special meetings shall be held at the call of the chairman or on written request of two or more members.
(3) Each member may, by filing with the secretary, designate a deputy or alternate to perform his duties.
(4) The council shall act only in an advisory capacity to the department on matters relating to water pollution.

History: En. Sec. 132, Ch. 197, L. 1967; amd. Sec. 10, Ch. 21, L. 1971; amd. Sec. 64, Ch. 349, L. 1974; R.C.M. 1947, 69-4812.

Part 3

Classification and Standards

75-5-301. Classification and standards for state waters. The board shall:
(1) establish and modify the classification of all waters in accordance with their present and future most beneficial uses;
(2) formulate standards of water purity and classification of water according to its most beneficial uses, giving consideration to the economics of waste treatment and prevention;
(3) review, from time to time at intervals of not more than 3 years, established classifications of waters and standards of water purity and classification.

History: En. Sec. 6, Ch. 21, L. 1971; amd. Sec. 2, Ch. 506, L. 1973; amd. Sec. 62, Ch. 349, L. 1974; amd. Sec. 5, Ch. 455, L. 1975; amd. Sec. 3, Ch. 444, L. 1977; R.C.M. 1947, 69-4808.2(part).

75-5-302. Revised classifications not to lower water quality standards — exception. In revising classifications or standards or in adopting new classifications or standards, the board may not so formulate standards of water purity or classify any state water as to lower any water quality standard applicable to any state water below the level applicable under the classifications and standards adopted except upon a finding that a particular state water has been classified under a standard or classification of water quality that is higher than the actual water quality that existed at the time of classification and only if the action is taken pursuant to 75-5-307.

History: **En. Sec. 6, Ch. 21, L. 1971; amd. Sec. 2, Ch. 506, L. 1973; amd. Sec. 62, Ch. 349, L. 1974; amd. Sec. 5, Ch. 455, L. 1975; amd. Sec. 3, Ch. 444, L. 1977; R.C.M. 1947, 69-4808.2(1)(c)(i).**

75-5-303. Nondegradation policy. The board shall require:

(1) that any state waters whose existing quality is higher than the established water quality standards be maintained at that high quality unless it has been affirmatively demonstrated to the board that a change is justifiable as a result of necessary economic or social development and will not preclude present and anticipated use of these waters; and

(2) any industrial, public, or private project or development which would constitute a new source of pollution or an increased source of pollution to high-quality waters, referred to in subsection (1), to provide the degree of waste treatment necessary to maintain that existing high water quality.

History: **En. Sec. 6, Ch. 21, L. 1971; amd. Sec. 2, Ch. 506, L. 1973; amd. Sec. 62, Ch. 349, L. 1974; amd. Sec. 5, Ch. 455, L. 1975; amd. Sec. 3, Ch. 444, L. 1977; R.C.M. 1947, 69-4808.2(1)(c)(ii), (1)(c)(iii).**

75-5-304. Adoption of standards — pretreatment, effluent, performance. The board shall adopt pretreatment standards for wastewater discharged into a municipal disposal system, adopt effluent standards as defined in 75-5-103, adopt toxic effluent standards and prohibitions, and establish standards of performance for new point source discharges.

History: **En. Sec. 6, Ch. 21, L. 1971; amd. Sec. 2, Ch. 506, L. 1973; amd. Sec. 62, Ch. 349, L. 1974; amd. Sec. 5, Ch. 455, L. 1975; amd. Sec. 3, Ch. 444, L. 1977; R.C.M. 1947, 69-4808.2(1)(h).**

75-5-305. Adoption of requirements for treatment of wastes. The board may establish minimum requirements for the treatment of wastes.

History: **En. Sec. 6, Ch. 21, L. 1971; amd. Sec. 2, Ch. 506, L. 1973; amd. Sec. 62, Ch. 349, L. 1974; amd. Sec. 5, Ch. 455, L. 1975; amd. Sec. 3, Ch. 444, L. 1977; R.C.M. 1947, 69-4808.2(2)(b).**

75-5-306. Purer than natural unnecessary — dams. (1) It is not necessary that wastes be treated to a purer condition than the natural condition of the receiving stream as long as the minimum treatment requirements established under this chapter are met.

(2) "Natural" refers to conditions or material present from runoff or percolation over which man has no control or from developed land where all reasonable land, soil, and water conservation practices have been applied. Conditions resulting from the reasonable operation of dams at July 1, 1971, are natural.

History: **En. Sec. 121, Ch. 197, L. 1967; amd. Sec. 1, Ch. 21, L. 1971; amd. Sec. 1, Ch. 455, L. 1975; R.C.M. 1947, 69-4801(2).**

75-5-307. Hearings required for classification, formulation of standards, and rulemaking. (1) Before streams are classified or standards established or modified or rules made, revoked, or modified, the board shall hold a public hearing. Notice of the hearing specifying the waters concerned and the classification, standards, or modification of them and any rules proposed to be made, revoked, or modified shall be published at least once a week for 3 consecutive weeks in a daily newspaper of general circulation in the area affected. Notice shall also be mailed directly to persons the board believes may be affected by the proposed action. The council shall be given not less than 30 days prior to first publication to comment on the proposed action.

(2) At a hearing held under this section, the board shall give all interested persons reasonable opportunity to submit data, views, or arguments, orally or in writing. The board may make rules for the orderly conduct of the hearing but need not require compliance with the rules of evidence or procedure applicable to hearings held under 75-5-611.

History: En. Sec. 134, Ch. 197, L. 1967; amd. Sec. 12, Ch. 21, L. 1971; R.C.M. 1947, 69-4814.

Part 4

Permits

75-5-401. Board rules for permits. (1) The board shall adopt rules:

(a) governing application for permits to discharge sewage, industrial wastes, or other wastes into state waters, including rules requiring the filing of plans and specifications relating to the construction, modification, or operation of disposal systems;

(b) governing the issuance, denial, modification, or revocation of permits.

(2) The rules shall allow the issuance or continuance of a permit only if the department finds that operation consistent with the limitations of the permit will not result in pollution of any state waters, except that the rules may allow the issuance of a temporary permit under which pollution may result if the department insures that such permit contains a compliance schedule designed to meet all applicable effluent standards and water quality standards in the shortest reasonable period of time.

(3) The rules shall provide that the department may revoke a permit if the department finds that the holder of the permit has violated its terms, unless the department also finds that the violation was accidental and unforeseeable and that the holder of the permit corrected the condition resulting in the violation as soon as was reasonably possible.

History: En. Sec. 6, Ch. 21, L. 1971; amd. Sec. 2, Ch. 506, L. 1973; amd. Sec. 62, Ch. 349, L. 1974; amd. Sec. 5, Ch. 455, L. 1975; amd. Sec. 3, Ch. 444, L. 1977; R.C.M. 1947, 69-4808.2(1)(d), (1)(e).

75-5-402. Duties of department. The department shall:

(1) issue, suspend, revoke, modify, or deny permits to discharge sewage, industrial wastes, or other wastes into state waters, consistently with rules made by the board;

(2) examine plans and other information needed to determine whether a permit should be issued or suggest changes in plans as a condition to the issuance of a permit;

(3) clearly specify in any permit any limitations imposed as to the volume, strength, and other significant characteristics of the waste to be discharged

History: En. Sec. 7, Ch. 21, L. 1971; amd. Sec. 3, Ch. 506, L. 1973; amd. Sec. 63, Ch. 349, L. 1974; amd. Sec. 6, Ch. 455, L. 1975; amd. Sec. 4, Ch. 444, L. 1977; R.C.M. 1947, 69-4809.1(1)(a) thru (1)(c).

75-5-403. Denial or modification of permit. (1) If the department denies an application for a permit or modifies a permit, the department shall give written notice of its action to the applicant or holder and he may request a hearing before the board, in the manner stated in 75-5-611, for the purpose of petitioning the board to reverse or modify the action of the department. Such hearing shall be held within 30 days after receipt of written request. After the hearing, the board shall affirm, modify, or reverse the action of the department. If the holder does not request a hearing before the board, modification of a permit shall be effective 30 days after receipt of notice by the holder unless the department specifies a later date. If the holder does request a hearing before the board, no order modifying his permit shall be effective until 20 days after he has received notice of the action of the board.

(2) This section does not apply to any modification made in permit conditions at the time of reissuance, but only to those modifications made in existing permits during their terms.

History: En. Sec. 14, Ch. 21, L. 1971; amd. Sec. 4, Ch. 455, L. 1975; R.C.M. 1947, 69-4807.1(1).

75-5-404. Suspension or revocation of permit — procedure. If the department suspends or revokes a permit because it has reason to believe that the holder has violated this chapter, the department may specify that the suspension or revocation is effective immediately if the department finds that the violation is likely to continue and will cause pollution, the harmful effects of which will not be remedied immediately on the cessation of the violation. Upon petition by the holder of the permit, the board shall grant the holder a hearing, to be conducted in the manner specified in 75-5-611, and shall issue an order affirming, modifying, or reversing the action of the department. The order of the board shall be effective immediately unless the board directs otherwise.

History: En. Sec. 14, Ch. 21, L. 1971; amd. Sec. 4, Ch. 455, L. 1975; R.C.M. 1947, 69-4807.1(2).

Part 5

Financial Provisions

75-5-501. Board to control state matching funds for construction of water pollution control facilities. (1) The board shall control funds appropriated by the state for the purpose of providing matching funds to local governments for the construction of water pollution control facilities.

(2) The board shall adopt rules and establish standards for the use of such matching funds by local governments in the planning and construction of local water pollution control facilities.

(3) Funds appropriated under this section shall be used only to provide an increase in the aid from the federal government not otherwise obtainable and may not exceed 25% of the total cost of the project as participated in by the federal water pollution control administration.

History: En. Sec. 1, Ch. 165, L. 1969; amd. Sec. 61, Ch. 349, L. 1974; R.C.M. 1947, 69-4808.1.

75-5-502. Board authorized to accept loans and grants. The board may accept loans and grants from the federal government and other sources to carry out the provisions of this chapter.

History: En. Sec. 6, Ch. 21, L. 1971; amd. Sec. 2, Ch. 506, L. 1973; amd. Sec. 62, Ch. 349, L. 1974; amd. Sec. 5, Ch. 455, L. 1975; amd. Sec. 3, Ch. 444, L. 1977; R.C.M. 1947, 69-4808.2(2)(a).

75-5-503. Department authorized to accept loans and grants. The department may accept loans and grants from the federal government and other sources to carry out the provisions of this chapter.

History: En. Sec. 7, Ch. 21, L. 1971; amd. Sec. 3, Ch. 506, L. 1973; amd. Sec. 63, Ch. 349, L. 1974; amd. Sec. 6, Ch. 455, L. 1975; amd. Sec. 4, Ch. 444, L. 1977; R.C.M. 1947, 69-4809.1(2).

75-5-504 through 75-5-510 reserved.

75-5-511. Sewage system operators authorized to adopt charges and rates for users. (1) A municipality or other entity operating a sewage system may adopt a system of charges and rates to assure that each recipient of treatment works services within the municipality's jurisdiction or service area will pay its proportionate share of the costs of operation, maintenance, and replacement of any treatment works facilities or services provided by the municipality or other entity.

(2) A municipality or other entity operating a sewage system may require industrial users of its treatment works to pay to the municipality or other entity that portion of the cost of construction of the treatment works which is allocable to the treatment of such industrial user's wastes. The department may determine whether the payment required of the industrial user for the portion of the cost of the construction of the treatment works is properly allocable to the treatment of the industrial user's wastes.

History: En. Sec. 14, Ch. 455, L. 1975; R.C.M. 1947, 69-4808.4(1), (2).

75-5-512. Uses allowed for revenues. A municipality or other entity operating a sewage system may retain the amounts of the revenues derived from the payment of costs by industrial users of its treatment works services and expend such revenues, together with interest thereon, for:

(1) repayment to applicable agencies of government of any grants or loans made to the municipality or other entity operating a sewage system for construction of the treatment works;

(2) future expansion and reconstruction of the treatment works; and

(3) other municipal purposes.

History: En. Sec. 14, Ch. 455, L. 1975; R.C.M. 1947, 69-4808.4(3).

75-5-513. Sewage system operators to keep records — department's power to inspect and audit. A municipality or other entity operating sewage systems shall keep records, financial statements, and books regarding its rates and charges and amounts collected on account of its treatment works and how such revenues are allocated. The department may inspect such records, financial statements, and books, audit them or cause them to be audited at such intervals as deemed necessary.

History: En. Sec. 14, Ch. 455, L. 1975; R.C.M. 1947, 69-4808.4(4).

75-5-514. When board to establish rates and collect charges. (1) In the event a municipality or other entity operating sewage systems fails, neglects, or refuses when required by the department to adopt the system of charges and rates authorized by 75-5-511, the board may adopt a system of charges and rates as provided for in 75-5-511(1) and collect, administer, and apply such revenues for the purposes of 75-5-512.

(2) In lieu of proceeding in the manner set forth in subsection (1) of this section, the department may institute proceedings at law or in equity to enforce compliance with or restrain violations of 75-5-511 through 75-5-513.

History: En. Sec. 14, Ch. 455, L. 1975; R.C.M. 1947, 69-4808.4(5), (6).

75-5-515. Determination of costs payable by users. In determining the amount of treatment works costs to be paid by recipients of treatment works services, the municipality or other entity operating sewage systems or, if applicable, the board shall consider the strength, volume, types, and delivery flow rate characteristics of the waste; the nature, location, and type of treatment works; the receiving waters; and such other factors as deemed necessary.

History: En. 69-4808.5 by Sec. 15, Ch. 455, L. 1975; R.C.M. 1947, 69-4808.5.

Part 6

Enforcement, Appeal, and Penalties

75-5-601. Clean-up orders. The department shall issue orders to any person to clean up any material which he or his employee, agent, or subcontractor has accidentally or purposely dumped, spilled, or otherwise deposited in or near state waters and which may pollute them.

History: En. Sec. 7, Ch. 21, L. 1971; amd. Sec. 3, Ch. 506, L. 1973; amd. Sec. 63, Ch. 349, L. 1974; amd. Sec. 6, Ch. 455, L. 1975; amd. Sec. 4, Ch. 444, L. 1977; R.C.M. 1947, 69-4809.1(1)(f).

75-5-602. Power to require monitoring. In order to carry out the objectives of this chapter and to effectively monitor the discharge of sewage, industrial wastes, and other wastes into state waters, the department may require the owner or operator of any point source, or the owner or operator of any facility that discharges into a municipal sewage system and to which pretreatment standards promulgated under this chapter apply, to:

(1) establish and maintain records;

(2) make reports;

(3) install, use, and maintain monitoring equipment or methods, including biological monitoring techniques;

(4) sample effluents using specified monitoring methods at designated locations and intervals;

(5) provide other information as may be reasonably required by the department.

History: En. 69-4809.2 by Sec. 4, Ch. 506, L. 1973; amd. Sec. 7, Ch. 455, L. 1975; R.C.M. 1947, 69-4809.2(1).

75-5-603. Power to inspect. The authorized representative of the department, upon presentation of his credentials, may at reasonable times enter upon any public or private property to:

(1) investigate conditions relating to pollution of state waters or violations of permit conditions;

(2) have access to and copy any records required under this chapter;

(3) inspect any monitoring equipment or method required under 75-5-602(3); and

(4) sample any effluents which the owner or operator of such source is required to sample under 75-5-602(4).

History: En. 69-4809.2 by Sec. 4, Ch. 506, L. 1973; amd. Sec. 7, Ch. 455, L. 1975; R.C.M. 1947, 69-4809.2(2).

75-5-604. Information obtained to relate to standards. Any records, reports, or information obtained under 75-5-602 and 75-5-603 shall, in the case of effluent data, be related to any applicable effluent limitations, toxic, pretreatment, or new source performance standards.

History: En. 69-4809.2 by Sec. 4, Ch. 506, L. 1973; amd. Sec. 7, Ch. 455, L. 1975; R.C.M. 1947, 69-4809.2(3).

75-5-605. Prohibited activity. (1) It is unlawful to:

(a) cause pollution as defined in 75-5-103 of any state waters or to place or cause to be placed any wastes in a location where they are likely to cause pollution of any state waters;

(b) violate any provision set forth in a permit or stipulation, including but not limited to limitations and conditions contained therein;

(c) violate any order issued pursuant to this chapter; or

(d) violate any provision of this chapter.

(2) It is unlawful to carry on any of the following activities without a current permit from the department:

(a) construct, modify, or operate a disposal system which discharges into any state waters;

(b) construct or use any outlet for the discharge of sewage, industrial wastes, or other wastes into any state waters; or

(c) discharge sewage, industrial wastes, or other wastes into any state waters.

History: En. Sec. 126, Ch. 197, L. 1967; amd. Sec. 5, Ch. 21, L. 1971; amd. Sec. 3, Ch. 455, L. 1975; amd. Sec. 2, Ch. 444, L. 1977; R.C.M. 1947, 69-4806.

75-5-606 through 75-5-610 reserved.

75-5-611. Violation of chapter — notice and hearing. (1) When the department has reason to believe that a violation of this chapter or a rule made under it has occurred, it may have written notice served personally or by mail on the alleged violator or his agent. The notice shall state the provision alleged to be violated, the facts alleged to constitute the violation, the nature of corrective action which the department requires, and the time within which the action is to be taken. For the purposes of this chapter, service by mail is complete on the date of mailing.

(2) In a notice given under subsection (1) of this section, the department may require the alleged violator to appear before the board for a public hearing and to answer the charges made against him. The hearing shall be held no sooner than 15 days after service of the notice, except that the board may set an earlier date for hearing if it is requested to do so by the alleged violator. The board may set a later date for hearing at the request of the alleged violator if the alleged violator shows good cause for delay.

(3) If the department does not require an alleged violator to appear before the board for a public hearing, he may request the board to conduct the hearing. The request shall be in writing and shall be filed with the department no later than 30 days after service of a notice under subsection (1) of this section. If a request is filed, a hearing shall be held within a reasonable time.

(4) If a hearing is held under this section, it shall be public and shall, if the board considers it practicable, be held in a county in which the violation is alleged to have occurred.

(5) After a hearing or on failure of an alleged violator to make a timely request for a hearing, the board may issue an appropriate order for the prevention, abatement, or control of pollution. It shall state the date or dates by which a violation shall cease and may prescribe timetables for necessary action in preventing, abating, or controlling the pollution.

(6) The alleged violator may petition the board for a rehearing on the basis of new evidence, which petition the board may grant for good cause shown.

(7) In addition to or instead of issuing an order, the board may direct the department to initiate appropriate action for recovery of a penalty under 75-5-631, 75-5-632, 75-5-633, or 75-5-635.

History: En. Sec. 13, Ch. 21, L. 1971; amd. Sec. 65, Ch. 349, L. 1974; amd. Sec. 8, Ch. 455, L. 1975; R.C.M. 1947, 69-4820.

75-5-612. Additional sanctions authorized. In addition to all other remedies created by this chapter, the department is authorized to take appropriate enforcement action on its own initiative to prevent, abate, and control:

(1) the pollution of state waters;

(2) any violation of a condition or limitation imposed by a permit issued under 75-5-402(1); or

(3) any violation of rules relating to pretreatment standards.

History: En. 69-4820.1 by Sec. 5, Ch. 506, L. 1973; amd. Sec. 9, Ch. 455, L. 1975; amd. Sec. 10, Ch. 140, L. 1977; amd. Sec. 4, Ch. 308, L. 1977; amd. Sec. 5, Ch. 444, L. 1977; R.C.M. 1947, 69-4820.1(1).

75-5-613. Compliance orders. In furtherance of 75-5-612, a person violating a condition, limitation, standard, or other requirement established pursuant to this chapter may be served with a compliance order issued by the department. The order must specify the condition, limitation, standard, or other requirement violated and must set a time for compliance. However, in establishing a time for compliance, the department shall take into account the seriousness of the violation and any good-faith efforts that have been made to comply with the condition, limitation, standard, or other requirement that has been violated. The compliance order issued under this section shall be served either personally by a person qualified to perform service under the Montana Rules of Civil Procedure or by certified mail.

History: En. 69-4820.1 by Sec. 5, Ch. 506, L. 1973; amd. Sec. 9, Ch. 455, L. 1975; amd. Sec. 10, Ch. 140, L. 1977; amd. Sec. 4, Ch. 308, L. 1977; amd. Sec. 5, Ch. 444, L. 1977; R.C.M. 1947, 69-4820.1(2).

75-5-614. Injunctions authorized. (1) The department is authorized to commence a civil action seeking appropriate relief, including a permanent or temporary injunction, for a violation which would be subject to a compliance order under 75-5-613. An action under this subsection may be commenced in the district court of the county in which the defendant is located or resides or is doing business or any county where a violation occurs or is threatened if the defendant cannot be located in Montana, and the court shall have jurisdiction to restrain the violation and to require compliance.

(2) The department may bring an action for an injunction against the continuation of an alleged violation of the terms or conditions of a permit issued by the department or any rule or effluent standard promulgated under this chapter or against a person who fails to comply with an emergency order issued by the department under 75-5-621 or a final order of the board. The court to which the department applies for an injunction may issue a temporary injunction if it finds that there is reasonable cause to believe that the allegations of the department are true, and it may issue a temporary restraining order pending action on the temporary injunction.

History: (1)En. 69-4820.1 by Sec. 5, Ch. 506, L. 1973; amd. Sec. 9, Ch. 455, L. 1975; amd. Sec. 10, Ch. 140, L. 1977; amd. Sec. 4, Ch. 308, L. 1977; amd. Sec. 5, Ch. 444, L. 1977; Sec. 69-4820.1, R.C.M. 1947; (2)En. Sec. 19, Ch. 21, L. 1971; amd. Sec. 68, Ch. 349, L. 1974; amd. Sec. 12, Ch. 455, L. 1975; Sec. 69-4825, R.C.M. 1947; R.C.M. 1947, 69-4820.1(3), 69-4825.

75-5-615. Violators subject to penalties. (1) A person found to be in violation of a condition, limitation, standard, or other requirement established pursuant to 75-5-612 through 75-5-614 is subject to the penalty provisions of 75-5-631, 75-5-632, 75-5-633, and 75-5-635.

(2) For the purpose of this section, the term "person" means, in addition to the definition contained in 75-5-103, any responsible corporate officer.

History: En. 69-4820.1 by Sec. 5, Ch. 506, L. 1973; amd. Sec. 9, Ch. 455, L. 1975; amd. Sec. 10, Ch. 140, L. 1977; amd. Sec. 4, Ch. 308, L. 1977; amd. Sec. 5, Ch. 444, L. 1977; R.C.M. 1947, 69-4820.1 (4), (5); amd. Sec. 6, Ch. 68, L. 1979.

75-5-616. Enforcement of permits and chapter. The department shall take such actions as are authorized or required under 75-5-612 through 75-5-615 to insure that the terms and conditions of issued permits are complied with and to insure that violations of this chapter are appropriately prosecuted.

History: En. Sec. 7, Ch. 21, L. 1971; amd. Sec. 3, Ch. 506, L. 1973; amd. Sec. 63, Ch. 349, L. 1974; amd. Sec. 6, Ch. 455, L. 1975; amd. Sec. 4, Ch. 444, L. 1977; R.C.M. 1947, 69-4809.1(1)(g).

75-5-617 through 75-5-620 reserved.

75-5-621. Emergencies. (1) Notwithstanding any other provisions of this chapter, if the department finds that a person is committing or is about to commit an act in violation of this chapter or an order or rule issued under it which, if it occurs or continues, will cause substantial pollution the harmful effects of which will not be remedied immediately after the commission or cessation of the act, the department shall order the person to stop, avoid, or moderate the act so that the substantial injury will not occur. The order shall be effective immediately upon receipt by the person to whom it is directed, unless the department provides otherwise.

(2) Notice of the order shall conform to the requirements of 75-5-611(1) so far as practicable. The notice shall indicate that the order is an emergency order.

(3) Upon issuing such an order, the department shall fix a place and time for a hearing before the board, not later than 5 days thereafter unless the person to whom the order is directed shall request a later time. The department may deny a request for a later time if it finds that the person to whom the order is directed is not complying with the order. The hearing shall be conducted in the manner specified in 75-5-611. As soon as practicable after the hearing, the board shall affirm, modify, or set aside the order of the department. The order of the board shall be accompanied by the statement specified in 75-5-611(5). An action for review of the order of the board may be initiated in the manner specified in 75-5-641. The initiation of such an action or taking of an appeal may not stay the effectiveness of the order unless the court finds that the board did not have reasonable cause to issue an order under this section.

History: En. Sec. 18, Ch. 21, L. 1971; amd. Sec. 11, Ch. 140, L. 1977; R.C.M. 1947, 69-4824.

75-5-622. Additional emergency powers. Notwithstanding any other provisions of this chapter, the department, upon receipt of evidence that a pollution source or combination of sources is endangering the health, welfare, or livelihood of a person, may bring suit in the district court of any county in which the defendant is located or resides or is doing business to enjoin the discharge of pollutants causing or contributing to the alleged pollution.

History: En. 69-4824.1 by Sec. 7, Ch. 506, L. 1973; R.C.M. 1947, 69-4824.1.

75-5-623 through 75-5-630 reserved.

75-5-631. Civil penalties — injunctions not barred. (1) A person who violates this chapter or a rule, permit, effluent standard, or order issued under the provisions of this chapter shall be subject to a civil penalty not to exceed $10,000. Each day of violation constitutes a separate violation.

(2) Action under this section does not bar enforcement of this chapter or of rules or orders issued under it by injunction or other appropriate remedy.

(3) The department shall institute and maintain any enforcement proceedings in the name of the state.

History: En. Sec. 17, Ch. 21, L. 1971; amd. Sec. 6, Ch. 506, L. 1973; amd. Sec. 67, Ch. 349, L. 1974; amd. Sec. 11, Ch. 455, L. 1975; R.C.M. 1947, 69-4823(1), (3).

75-5-632. Criminal penalties. A person who willfully or negligently violates 75-5-605 or any pretreatment standard established pursuant to this chapter is guilty of an offense and subject to a fine not to exceed $25,000 per day of violation or imprisonment for not more than 1 year, or both. Following an initial conviction under this section, subsequent convictions shall subject a person to a fine of not more than $50,000 per day of violation or imprisonment for not more than 2 years, or both.

History: En. Sec. 17, Ch. 21, L. 1971; amd. Sec. 6, Ch. 506, L. 1973; amd. Sec. 67, Ch. 349, L. 1974; amd. Sec. 11, Ch. 455, L. 1975; R.C.M. 1947, 69-4823(2).

75-5-633. Penalties for false statements and falsifying monitoring. Any person who knowingly makes any false statement, representation, or certification in any application, record, report, plan, or other document filed or required to be maintained under this chapter or who falsifies, tampers with, or knowingly renders inaccurate any monitoring device or method required to be maintained under this chapter shall upon conviction be punished by a fine of not more than $10,000 or by imprisonment for not more than 6 months, or both.

History: En. Sec. 17, Ch. 21, L. 1971; amd. Sec. 6, Ch. 506, L. 1973; amd. Sec. 67, Ch. 349, L. 1974; amd. Sec. 11, Ch. 455, L. 1975; R.C.M. 1947, 69-4823(6).

75-5-634. Fines to go to general fund. Fines collected shall be deposited to the state general fund.

History: En. Sec. 17, Ch. 21, L. 1971; amd. Sec. 6, Ch. 506, L. 1973; amd. Sec. 67, Ch. 349, L. 1974; amd. Sec. 11, Ch. 455, L. 1975; R.C.M. 1947, 69-4823(5).

75-5-635. Costs and expenses — recovery by department. In a civil action initiated by the department under this chapter, the department may ask for and the court is authorized to assess a violator for the cost of the investigation or monitoring survey which led to the establishment of the violation and any expense incurred by the state in removing, correcting, or terminating any of the adverse effects upon water quality resulting from the unauthorized discharge of pollutants.

History: En. Sec. 17, Ch. 21, L. 1971; amd. Sec. 6, Ch. 506, L. 1973; amd. Sec. 67, Ch. 349, L. 1974; amd. Sec. 11, Ch. 455, L. 1975; R.C.M. 1947, 69-4823(7).

75-5-636. Action by other parties. A person, association, corporation, or agency of the state or federal government may apply to the department protesting a violation of this chapter. The department shall make an investigation and make a written report to the person, association, corporation, or agency which made the protest. If a violation is established by the investigation of the department, appropriate enforcement action shall be taken.

History: En. Sec. 20, Ch. 21, L. 1971; amd. Sec. 69, Ch. 349, L. 1974; amd. Sec. 13, Ch. 455, L. 1975; R.C.M. 1947, 69-4826.

75-5-637 through 75-5-640 reserved.

75-5-641. Appeals from board orders — review by district court. (1) An appeal of an order of the board shall be in the district court of the county in which the alleged source of pollution is located.

(2) A person interested in the order may intervene, in the manner provided by the rules of civil procedure, if he shows good cause. An intervenor is a party for the purposes of this chapter.

(3) The attorney general shall represent the board if requested, or the department may appoint special counsel for the proceedings, subject to the approval of the attorney general.

(4) The initiation of an action for review or the taking of an appeal does not stay the effectiveness of any order of the board unless the court finds that there is probable cause to believe:

(a) that refusal to grant a stay will cause serious harm to the affected party; and

(b) that any violation found by the board will not continue or, if it does continue, any harmful effects on state waters will be remedied immediately on the cessation of the violation.

(5) If a court does not stay the effectiveness of an order of the board, it may enforce compliance with that order by issuing a temporary restraining order or an injunction at the request of the board.

History: En. Sec. 15, Ch. 21, L. 1971; amd. Sec. 66, Ch. 349, L. 1974; R.C.M. 1947, 69-4821.

APPENDIX 4a.

MONTANA DEPARTMENT OF HEALTH AND ENVIRONMENTAL SCIENCES
Environmental Sciences Division
Water Quality Bureau
Helena, Montana 59620

Administrative Rules of Montana

Title 16, Chapter 20 - Water Quality

Sub-Chapter 6 - SURFACE WATER QUALITY STANDARDS

Rule 16.20.601	Policy
16.20.602	Application and Composition of Surface Water Quality Standards
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16.20.604	Water-use Classifications -- Clark Fork-Columbia River Drainage Except the Flathead and Kootenai River Drainages
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Rule 16.20.617	A-1 Classification
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16.20.643	Metal Limits

Sub-Chapter 6

Surface Water Quality Standards

16.20.601 POLICY The following standards are adopted to conserve water by protecting, maintaining, and improving the quality and potability of water for public water supplies, wildlife, fish and aquatic life, agriculture, industry, recreation, and other beneficial uses. (History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80.)

16.20.602 APPLICATION AND COMPOSITION OF SURFACE WATER QUALITY STANDARDS (1) The standards in this sub-chapter are adopted to establish maximum allowable changes in surface water quality and to establish a basis for limiting the discharge of pollutants which affect prescribed beneficial uses of surface waters.

(2) The surface water quality standards are composed of all rules of this sub-chapter.

(3) The provisions of ARM 16.20.631 through 16.20.635 and 16.20.641 and 16.20.642 apply to all surface waters unless they conflict with ARM 16.20.615 through 16.20.624 in which case the requirements of ARM 16.20.615 through 16.20.624 prevail. (History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80.)

16.20.603 DEFINITIONS In this sub-chapter the following terms shall have the meanings indicated below and shall be supplemental to the definitions given in section 75-5-103, MCA:

(1) "Conventional water treatment" means in order of application the processes of coagulation, sedimentation, filtration and chlorination. If determined necessary by the department it also includes taste and odor control and lime softening.

(2) "Conduit" means any artificial or natural duct, either open or closed, capable of conveying liquids or pollutants.

(3) "Dewatered stream" means a perennial or intermittent stream from which water has been removed for one or more beneficial uses.

(4) "EPA" means the U.S. Environmental Protection Agency.

(5) "Ephemeral stream" means a stream or part of a stream which flows only in direct response to precipitation in the immediate water-shed or in response to the melting of a cover of snow and ice and whose channel bottom is always above the local water table.

(6) "Geometric mean" means the value obtained by taking the Nth root of the product of the measured values where zero values for measured values are taken to be the detection limit.

(7) "Intermittent stream" means a stream or reach of a stream that is below the local water table for at least some part of the year, and obtains its flow from both surface runoff and ground water discharge.

(8) "Mixing zone" means the area of a water body contiguous to an effluent with characteristics qualitatively or quantitatively different from those of the receiving water. The mixing zone is a place where effluent and receiving water mix and not a place where effluents are treated. Water quality standards do not apply in the mixing zone for those parameters regulated by a MPDES or NPDES permit.

(9) "MPDES" means the Montana Pollutant Discharge Elimination System.

(10) "NPDES" means the National Pollutant Discharge Elimination System.

(11) "Naturally occurring" means conditions or material present from runoff or percolation over which man has no control or from developed land where all reasonable land, soil and water conservation practices have been applied. Conditions resulting from the reasonable operation of dams in existence as of July 1, 1971 are natural.

(12) "Nonpoint source" means the source of pollutants which originates from diffuse runoff, seepage, drainage, or infiltration.

(13) "Pesticide" means insecticides, herbicides, rodenticides, fungicides or any substance or mixture of substances intended for preventing, destroying, controlling, repelling, altering life processes, or mitigating any insects, rodents, nematodes, fungi, weeds and other forms of plant or animal life.

(14) "Pollutants" means sewage, industrial wastes and other wastes as defined in sections 75-5-103(1),(2),(3), MCA.

(15) "Sediment" means solid material settled from suspension in a liquid; mineral or organic solid material that is being transported or has been moved from its site of origin by air, water or ice and has come to rest on the earth's surface, either above or below sea level; or inorganic or organic particles originating from weathering, chemical precipitation or biological activity.

(16) "Settleable solids" means inorganic or organic particles that are being transported or have been transported by water from the site or sites of origin and are settled or are capable of being settled from suspension.

(17) "Sewer" means a pipe or conduit that carries wastewater or drainage water.

(18) "Surface waters" means any waters on the earth's surface, including but not limited to, streams, lakes, ponds, and reservoirs; and irrigation and drainage systems discharging directly into a stream, lake, pond, reservoir or other surface water. Water bodies used solely for treating, transporting or impounding pollutants shall not be considered surface water.

(19) "Storm sewer" or "storm drain" means a pipe or conduit that carries storm water and surface water and street washings.

(20) "True color" means the color of water from which the turbidity has been removed.

(21) "Turbidity" means a condition in water or wastewater caused by the presence of suspended matter resulting in the scattering and absorption of light rays. (History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80.)

16.20.604 WATER-USE CLASSIFICATIONS -- CLARK FORK - COLUMBIA RIVER DRAINAGE EXCEPT THE FLATHEAD AND KOOTENAI RIVER DRAINAGES The water-use classifications adopted for the Clark Fork of the Columbia River drainage are as follows:

(1) Clark Fork River drainage except waters listed in subsections (1)(a) through (1)(n)	B-1
(a) Warm Springs drainage to Myers Dam near Anaconda	A-1
(b) Silver Bow Creek (mainstem) from the confluence of Blacktail Deer Creek to Warm Springs Creek	E
(The Anaconda Company tailings pond and Silver Bow Creek drainage from this pond to Blacktail Deer Creek and the tailings ponds at Warm Springs have no classification.)	
(c) Yankee Doodle Creek drainage to and including the North Butte water supply reservoir	A-Closed
(d) Basin Creek drainage to and including the South Butte water supply reservoir	A-Closed
(e) Clark Fork River (mainstem) from Warm Springs Creek to Cottonwood Creek (near Deer Lodge)	C-2
(f) Clark Fork River (mainstem) from Cottonwood Creek to the Little Blackfoot River	C-1
(g) Tin Cup Joe Creek drainage to the Deer Lodge water supply intake	A-Closed
(h) Georgetown Lake and tributaries above Georgetown Dam (headwaters of Flint Creek drainage)	A-1

(i) Fred Burr Lake and headwaters from source to the outlet of the lake (Philipsburg water supply) . . . . A-Closed

(j) South Boulder Creek drainage to the Philipsburg water supply intake A-1

(k) Rattlesnake drainage to the Missoula water supply intake . . . . A-Closed

(l) Packer and Silver Creek drainage (tributaries to the St. Regis River) to the Saltese water supply intake A-1

(m) Ashley Creek drainage to the Thompson Falls water supply intake . . . . A-Closed

(n) Pilgrim Creek drainage to the Noxon water supply intake A-1

(History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80.)

16.20.605 WATER-USE CLASSIFICATIONS -- FLATHEAD RIVER DRAINAGE The water-use classifications adopted for the Flathead River are as follows:

(1) Flathead River drainage above Flathead Lake except waters listed in subsections (1)(a) through (1)(g) A-1

(a) Essex Creek drainage to the Essex water supply intake . . . . A-Closed

(b) Stillwater River (mainstem) from Logan Creek to the Flathead River B-2

(c) Whitefish Lake and its tributaries A-1

(d) Whitefish River (mainstem) from the outlet of Whitefish Lake to the Stillwater River . . B-2

(e) Haskill Creek drainage to the Whitefish water supply intake A-1

(f) Ashley Creek (mainstem) from Smith Lake to bridge crossing on the airport road about one mile south of Kalispell B-2

(g) Ashley Creek (mainstem) from bridge crossing on airport road to the Flathead River . . . C-2

(2) Flathead Lake and its tributaries from Flathead River inlet to U.S. Highway 93 bridge at Polson except Swan River and portions of Hellroaring Creek as listed in subsections (2)(a) through (2)(c) but including Swan Lake proper and Lake Mary Ronan proper A-1

(a) Swan River drainage (except Swan Lake proper) B-1

(b) Hellroaring Creek drainage to the Polson water supply intake . . . . A-Closed

(c) Remainder of Hellroaring Creek drainage . . B-1

(3) Flathead River drainage below the highway bridge at Polson to confluence with Clark Fork River except tributaries listed in subsections (3)(a) through (3)(h) B-1

(a) Second Creek drainage to the Ronan water supply intake . . . . A-Closed

(b) Crow Creek (mainstem) from road crossing in Section 16, T20N, R20W to the Flathead River . . . B-2

(c) Little Bitterroot River (mainstem) from Hubbart Reservoir dam to the Flathead River B-2

(d) Hot Springs Creek drainage to the Hot Springs water supply intake . . . . A-Closed

(e) Hot Springs Creek (mainstem) from the Hot Springs water supply intake to the Little Bitterroot River . . . . E

(f) Tributaries to Hot Springs Creek (if any) from the Hot Springs water supply intake to the Little Bitterroot River B-1

(g) Mission Creek drainage to the St. Ignatius water supply intake A-1

(h) Mission Creek (mainstem) from U.S. Highway No. 93 crossing to the Flathead River B-2

(History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80; AMD, 1982 MAR p. 1745, Eff. 10/1/82.)

16.20.606 WATER-USE CLASSIFICATIONS -- KOOTENAI RIVER DRAINAGE The water-use classifications adopted for the Kootenai River are as follows:

(1) All waters except those listed in subsections (1)(a) through (1)(d) B-1

(a) Deep Creek drainage (tributary to the Tobacco River) to the Fortine water supply intake . . A-1

(b) Rainy Creek drainage to the W. R. Grace Company water supply intake A-1

(c) Rainy Creek (mainstem) from the W. R. Grace Company water supply intake to the Kootenai River C-1

(d) Flower Creek drainage to the Libby water supply intake A-1

(History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80.)

16.20.607 WATER-USE CLASSIFICATIONS -- MISSOURI RIVER DRAINAGE EXCEPT YELLOWSTONE, BELLE FOURCHE, AND LITTLE MISSOURI RIVER DRAINAGES The water-use classifications adopted for the Missouri River are as follows:

(1) Missouri River drainage to and including the Sun River drainage except tributaries listed in subsections (1)(a) through (1)(n) B-1

(a) East Gallatin River (mainstem) from Montana Highway No. 293 crossing about one-half mile north of Bozeman to Dry Creek about five miles east of Manhattan B-2

(b) Lyman and Sourdough (Bozeman) Creek drainages to the Bozeman water supply intakes . . . . A-Closed

(c) Remainder of the Lyman and Sourdough Creek drainages B-2

(d) Hyalite Creek drainage to the Bozeman water supply intake A-1

(e) Big Hole River drainage to Butte Water Company intake above Divide A-1

(f) Rattlesnake Creek drainage to the Dillon water supply intake A-1

(g) Indian Creek drainage to the Sheridan water supply intake A-1

(h) Basin Creek drainage to the Basin water supply intake A-1

(i) McClellan Creek drainage to the East Helena water supply intake A-1

(j) Prickly Pear Creek (mainstem) from the Montana Highway No. 433 crossing about one mile northwest of East Helena to Lake Helena . . . . E

(k) Ten Mile Creek drainage to the Helena water supply intake A-1

(l) Willow Creek drainage to the White Sulphur Springs water supply intake . . . . A-Closed

(m) Muddy Creek drainage (tributary to Sun River) . . . . E

(n) Sun River (mainstem) from Muddy Creek to the Missouri River B-3

(2) Missouri River drainage from Sun River to Rainbow Dam B-2

(3) Missouri River drainage from Rainbow Dam in Great Falls to the Marias River except waters listed in subsections (3)(a) through (3)(d). . B-3

(a) Belt Creek drainage to and including Otter Creek drainage except portion of O'Brien Creek listed in subsection (3)(a)(i) B-1

(i) O'Brien Creek drainage to the Neihart water supply intake A-1

(b) Belt Creek (mainstem) from Otter Creek to the Missouri River B-2

(c) Tributaries to Belt Creek from Otter Creek to the Missouri River B-1

(d) Highwood and Shonkin Creek drainages . . . B-1

(4) Marias River drainage except the tributaries listed in subsections (4)(a) through (4)(d). . B-2

(a) Cutbank Creek drainage except waters listed in subsections (4)(a)(i) and (ii). B-1

(i) Willow Creek (mainstem) from the Montana Highway No. 464 crossing about one-half mile north of Browning to Cutbank Creek B-2

(ii) Cutbank Creek (mainstem) from Old Maid Miller Coulee near Cut Bank to Birch Creek . . . B-2

(b) Two Medicine Creek drainage except for the waters listed in subsections (4)(b)(i) through (4)(b)(iii) B-1

(i) Midvale Creek drainage to the East Glacier water supply intake . . . . A-Closed

(ii) Summit Creek drainage to the Summit water supply intake . . . . A-Closed

(iii) Two Medicine Creek (mainstem) from Badger Creek to Birch Creek B-2

(c) Dry Fork Marias River (mainstem) from Interstate 15 crossing near Conrad to Marias River B-3

(d) Teton River drainage to and including Deep Creek near Choteau B-1

(5) Missouri River drainage from Marias River to Fort Peck Dam except waters listed in subsections (5)(a) through (5)(e) C-3

(a) Missouri River (mainstem) from Marias River to Fort Peck Dam B-3

(b) Eagle Creek drainage to but excluding Dog Creek B-1

(c) Judith River drainage except waters listed in subsections (5)(c)(i) through (5)(c)(v) . . B-1

(i) Big Spring Creek (mainstem) from the Mill Ditch headgate to the Judith River B-2

(ii) Judith River (mainstem) from Big Spring Creek to the Missouri River B-2

(iii) Sage Creek drainage below U.S. Highway 87 . . . . C-3

(iv) Wolf Creek drainage below U.S. Highway 87 . . . . C-3

(v) Tributaries to Judith River from Big Spring Creek to the Missouri River C-3

(d) Cow Creek drainage to but excluding Al's Creek B-1

(e) Musselshell River drainage except for the waters listed in subsections (5)(e)(i) through (5)(e)(v) B-1

(i) Musselshell River (mainstem) from Hopley Creek to Deadman's Basin Diversion Canal near Shawmut B-2

(ii) Musselshell River drainage below Deadman's Basin diversion canal above Shawmut except portions of Careless, Swimming Woman, Flatwillow and South Willow Creek drainages listed below C-3

(iii) Careless and Swimming Woman Creek drainage above their confluence north of Ryegate . . B-1

(iv) Flatwillow Creek drainage above U.S. Highway 87 crossing south of Grassrange B-2

(v) South Willow Creek drainage above county road bridge in T10N, R24E, Section 7 . . . . . B-1

(6) Missouri River drainage from Fort Peck Dam to the Milk River B-2

(7) Milk River drainage from source (or from the Glacier National Park Boundary) to the International Boundary B-1

(8) Milk River drainage from the International Boundary to the Missouri River except the tributaries listed in subsections (8)(a) through (8)(c) B-3

(a) Big Sandy Creek drainage to Town of Big Sandy infiltration wells B-1

(b) Beaver, Little Box Elder and Clear Creek drainage (near Havre) B-1

(c) People's Creek drainage to and including the South Fork of People's Creek drainage . . B-1

(9) Missouri River drainage from Milk River to North Dakota boundary except waters listed in subsections (9)(a) through (9)(d) C-3

(a) Missouri River (mainstem) from Milk River to North Dakota boundary B-3

(b) Wolf Creek drainage near Wolf Point B-2

(c) Antelope Creek drainage near Antelope . . . B-3

(d) Poplar River drainage B-2

(History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80; AMD, 1982 MAR p. 1745, Eff. 10/1/82.)

16.20.608 WATER-USE CLASSIFICATION -- YELLOWSTONE RIVER DRAINAGE The water-use classifications adopted for the Yellowstone River are as follows:

(1) Yellowstone River drainage to the Laurel water supply intake B-1

(2) Yellowstone River drainage from the Laurel water supply intake to the Billings water supply intake except the tributaries listed in subsections (2)(a) and (2)(b) B-2

(a) Clarks Fork Yellowstone River drainage from source to the Wyoming state line and from the Wyoming state line to and including Jack Creek near Bridger B-1

(b) Tributaries to the Clarks Fork Yellowstone River from Jack Creek (mainstem is B-2) to the Yellowstone River except the portion of West Fork of Rock Creek listed in subsection (2)(b)(i) B-1

(i) West Fork of Rock Creek drainage to the Red Lodge water supply intake A-1

(3) Yellowstone River drainage from the Billings water supply intake to the North Dakota state line and including the Big Horn River drainage except the waters listed in subsections (3)(a) through (3)(f) C-3

(a) Yellowstone River mainstem B-3

(b) Pryor Creek drainage to Interstate 90 . . . B-1

(c) Big Horn drainage above but excluding Williams Coulee near Hardin B-1

(d) Little Big Horn drainage above and including Lodgegrass Creek drainage near Lodge Grass B-1

(e) Remainder of the Little Big Horn drainage B-2

(f) Big Horn River mainstem from Williams Coulee to Yellowstone River B-2

(4) Yellowstone River drainage from Big Horn River to North Dakota boundary except waters listed in subsections (4)(a) through (4)(d). . C-3

(a) Yellowstone River mainstem from Big Horn River to North Dakota boundary B-3

(b) Tongue River (mainstem) from Wyoming boundary to Prairie Dog Coulee B-2

(c) Tongue River mainstem from Prairie Dog Coulee to Yellowstone River B-2

(d) Fox Creek drainage near Sidney B-2

(History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80.)

16.20.609 WATER-USE CLASSIFICATIONS -- LITTLE MISSOURI RIVER DRAINAGE -- BELLE FOURCHE DRAINAGE The water-use classifications adopted for all waters in the Little Missouri and Belle Fourche drainages are C-3

(History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80.)

16.20.610 WATER-USE CLASSIFICATIONS -- HUDSON BAY DRAINAGE The water-use classifications for the Hudson Bay drainage are:

(1) All waters outside Glacier National Park B-1

(History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80.)

16.20.611 WATER-USE CLASSIFICATIONS -- NATIONAL PARK, WILDERNESS AND PRIMITIVE AREA WATERS The water-use classifications for all national park, wilderness and primitive area waters are as follows:

(1) All waters even if classifications listed in ARM 16.20.604 through ARM 16.20.610 imply or state otherwise A-1

(History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80.)

Rules 16.20.612 through 16.20.614 reserved

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16.20.615 SPECIFIC SURFACE WATER QUALITY STANDARDS -- GENERAL (1) Specific surface water quality standards, along with general provisions in ARM 16.20.631 through 16.20.635 and ARM 16.20.641 and 16.20.642, protect the beneficial water uses set forth in the water-use descriptions for the following classifications of water.

(2) Standards for organisms of the coliform group are based on a minimum of five samples obtained during separate 24-hour periods during any consecutive 30-day period analyzed by the most probable number or equivalent membrane filter methods. (History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80.)

16.20.616 A-CLOSED CLASSIFICATION (1) Waters classified A-Closed are suitable for drinking, culinary and food processing purposes after simple disinfection.

(2) Public access and activities such as livestock grazing and timber harvest are to be controlled by the utility owner under conditions prescribed and orders issued by the department.

(3) For waters classified A-Closed the following specific water quality standards shall not be violated by any person:

(a) The geometric mean number of organisms in the coliform group must not exceed 50 per 100 milliliters.

(b) Dissolved oxygen criteria are not applicable for the classification.

(c) No change from natural pH is allowed.

(d) No increase above naturally occurring turbidity is allowed.

(e) No increase above naturally occurring water temperature is allowed.

(f) No increases are allowed above naturally occurring concentrations of sediment, settleable solids, oils, or floating solids, which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.

(g) No increase in true color is allowed.

(h) No increases of toxic or other deleterious substances, pesticides and organic and inorganic materials including heavy metals, above naturally occurring concentrations, are allowed.

(i) No increase in radioactivity above natural background levels is allowed. (History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80.)

16.20.617 A-1 CLASSIFICATION (1) Waters classified A-1 are suitable for drinking, culinary and food processing purposes after conventional treatment for removal of naturally present impurities.

(2) Water quality must be suitable for bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.

(3) For waters classified A-1 the following specific water quality standards shall not be violated by any person:

(a) The geometric mean number of organisms in the coliform group must not exceed 50 per 100 milliliters if resulting from domestic sewage.

(b) Dissolved oxygen concentration must not be reduced below 7.0 milligrams per liter.

(c) Induced variation of hydrogen ion concentration (pH) within the range of 6.5 to 8.5 must be less than 0.5 pH unit. Natural pH outside this range must be maintained without change. Natural pH above 7.0 must be maintained above 7.0.

(d) No increase above naturally occurring turbidity is allowed except as permitted in ARM 16.20.631 through 16.20.635 and ARM 16.20.641 and 16.20.642.

(e) A 1° F maximum increase above naturally occurring water temperature is allowed within the range of 32° F to 66° F; within the naturally occurring range of 66° F to 66.5° F, no discharge is allowed which will cause the water temperature to exceed 67° F; and where the naturally occurring water temperature is 66.5° F or greater, the maximum allowable increase in water temperature is 0.5° F. A 2° F per hour maximum decrease below naturally occurring water temperature is allowed when the water temperature is above 55° F, and a 2° F maximum decrease below naturally occurring water temperature is allowed within the range of 55° F to 32° F.

(f) No increases are allowed above naturally occurring concentrations of sediment, settleable solids, oils, or floating solids, which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.

(g) True color must not be increased more than two units above naturally occurring color.

(h) Concentrations of toxic or other deleterious substances which would remain in the water after conventional water treatment must not exceed the maximum contaminant levels set forth in the 1975 National Interim Primary Drinking Water Standards (40 CFR Part 141) or subsequent revisions or the 1979 National Secondary Drinking Water Standards (40 CFR Part 143) or subsequent revisions. The maximum allowable concentrations of toxic or deleterious substances also must not exceed acute or chronic problem levels as revealed by bioassay or other methods. The values listed in Quality Criteria for Water published by the Office of Water and Hazardous Materials, EPA, Washington, D.C. (The Red Book) shall be used as a guide to determine problem levels unless local conditions make these values inappropriate. In accordance with section 75-5-306(1), MCA, it is not necessary that wastes be treated to a purer condition than the natural condition of the receiving water. (History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80.)

16.20.618 B-1 CLASSIFICATION (1) Waters classified B-1 are suitable for drinking, culinary and food processing purposes, after conventional treatment; bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.

(2) For waters classified B-1 the following specific water quality standards shall not be violated by any person:

(a) During periods when the daily maximum water temperature is greater than 60° F., the geometric mean number of organisms in the fecal coliform group must not exceed 200 per 100 milliliters, nor are 10 percent of the total samples during any 30-day period to exceed 400 fecal coliforms per 100 milliliters.

(b) Dissolved oxygen concentration must not be reduced below 7.0 milligrams per liter.

(c) Induced variation of hydrogen ion concentration (pH) within the range of 6.5 to 8.5 must be less than 0.5 pH unit. Natural pH outside this range must be maintained without change. Natural pH above 7.0 must be maintained above 7.0.

(d) The maximum allowable increase above naturally occurring turbidity is 5 nephelometric turbidity units except as permitted in ARM 16.20.631 through 16.20.635 and ARM 16.20.641 and 16.20.642.

(e) A 1° F maximum increase above naturally occurring water temperature is allowed within the range of 32° F to 66° F; within the naturally occurring range of 66° F to 66.5° F, no discharge is allowed which will cause the water temperature to exceed 67° F; and where the naturally occurring water temperature is 66.5° F or greater, the maximum allowable increase in water temperature is 0.5° F. A 2° F per hour maximum decrease below naturally occurring water temperature is allowed when the water temperature is above 55° F, and a 2° F maximum decrease below naturally occurring water temperature is allowed within the range of 55° F to 32° F. This applies to all waters in the state classified B-1 except for Prickly Pear Creek from McClellan Creek to the Montana Highway No. 433 crossing where a 2° F maximum increase above naturally occurring water temperature is allowed within the range of 32° F to 65° F; within the naturally occurring range of 65° F to 66.5° F, no discharge is allowed which will cause the water temperature to exceed 67° F; and where the naturally occurring water temperature is 66.5° F or greater, the maximum allowable increase in water temperature is 0.5° F.

(f) No increases are allowed above naturally occurring concentrations of sediment, settleable solids, oils, or floating solids, which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.

(g) True color must not be increased more than five units above naturally occurring color.

(h) Concentrations of toxic or other deleterious substances which would remain in the water after conventional water treatment must not exceed the maximum contaminant levels set forth in the 1975 National Interim Primary Drinking Water Standards (40 CFR Part 141) or subsequent revisions or the 1979 National Secondary Drinking Water Standards (40 CFR Part 143) or subsequent revisions. The maximum allowable concentrations of toxic or deleterious substances also must not exceed acute or chronic problem levels as revealed by bioassay or other methods. The values listed in Quality Criteria for Water published by the Office of Water and Hazardous Materials, EPA, Washington, D.C. (The Red Book) shall be used as a guide to determine problem levels unless local conditions make these values inappropriate. In accordance with section 75-5-306(1), MCA, it is not necessary that wastes be treated to a purer condition than the natural condition of the receiving water. (History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80; AMD, 1982 MAR p. 1746, Eff. 10/1/82.)

16.20.619 B-2 CLASSIFICATION (1) Waters classified B-2 are suitable for drinking, culinary and food processing purposes, after conventional treatment; bathing, swimming and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.

(2) For waters classified B-2 the following specific water quality standards shall not be violated by any person:

(a) During periods when the daily maximum water temperature is greater than 60° F., the geometric mean number of organisms in the fecal coliform group must not exceed 200 per 100 milliliters, nor are 10 percent of the total samples during any 30-day period to exceed 400 fecal coliforms per 100 milliliters.

(b) Dissolved oxygen concentration must not be reduced below 7.0 milligrams per liter from October 1 through June 1 nor below 6.0 milligrams per liter from June 2 through September 30.

(c) Induced variation of hydrogen ion concentration (pH) within the range of 6.5 to 9.0 must be less than 0.5 pH unit. Natural pH outside this range must be maintained without change. Natural pH above 7.0 must be maintained above 7.0

(d) The maximum allowable increase above naturally occurring turbidity is 10 nephelometric turbidity units except as permitted in ARM 16.20.631 through 16.20.635 and ARM 16.20.641 and 16.20.642.

(e) A 1° F maximum increase above naturally occurring water temperature is allowed within the range of 32° F to 66° F; within the naturally occurring range of 66° F to 66.5° F, no discharge is allowed which will cause the water temperature to exceed 67° F; and where the naturally occurring water temperature is 66.5° F or greater, the maximum allowable increase in water temperature is 0.5° F. A 2° F per hour maximum decrease below naturally occurring water temperature is allowed when the water temperature is above 55° F, and a 2° F maximum decrease below naturally occurring water temperature is allowed within the range of 55° F to 32° F.

(f) No increases are allowed above naturally occurring concentrations of sediment, settleable solids, oils, or floating solids which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.

(g) True color must not be increased more than five units above naturally occurring color.

(h) Concentrations of toxic or other deleterious substances which would remain in the water after conventional water treatment must not exceed the maximum contaminant levels set forth in the 1975 National Interim Primary Drinking Water Standards (40 CFR Part 141) or subsequent revisions or the 1979 National Secondary Drinking Water Standards (40 CFR Part 143) or subsequent revisions. The maximum allowable concentrations of toxic or deleterious substances also must not exceed acute or chronic problem levels as revealed by bio-assay or other methods. The values listed in Quality Crtieria for Water published by the Office of Water and Hazardous Materials, EPA, Washington, D.C. (The Red Book) shall be used as a guide to determine problem levels unless local conditions make these values inappropriate. In accordance with section 75-5-306(1), MCA, it is not necessary that wastes be treated to a purer condition than the natural condition of the receiving water. (History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80; AMD, 1982 MAR p. 1746, Eff. 10/1/82.)

16.20.620 B-3 CLASSIFICATION (1) Waters classified B-3 are suitable for drinking, culinary and food processing purposes, after conventional treatment; bathing, swimming and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.

(2) For waters classified B-3 the following specific water quality standards shall not be violated by any person:

(a) During periods when the daily maximum water temperature is greater than 60° F., the geometric mean number of organisms in the fecal coliform group must not exceed 200 per 100 milliliters, nor are 10 percent of the total samples during any 30-day period to exceed 400 fecal coliforms per 100 milliliters.

(b) Dissolved oxygen concentration must not be reduced below 5.0 milligrams per liter.

(c) Induced variation of hydrogen ion concentration (pH) within the range of 6.5 to 9.0 must be less than 0.5 pH unit. Natural pH outside this range must be maintained without change. Natural pH above 7.0 must be maintained above 7.0.

(d) The maximum allowable increase above naturally occurring turbidity is 10 nephelometric turbidity units except as permitted in ARM 16.20.631 through 16.20.635 and ARM 16.20.641 and 16.20.642.

(e) A 3° F maximum increase above naturally occurring water temperature is allowed within the range of 32° F to 77° F; within the naturally occurring range of 77° F to 79.5° F, no thermal discharge is allowed which will cause the water temperature to exceed 80° F; and where the naturally occurring water temperature is 79.5° F or greater, the maximum allowable increase in water temperature is 0.5° F. A 2° F per hour maximum decrease below naturally occurring water temperature is allowed when the water temperature is above 55° F, and a 2° F maximum decrease below naturally occurring water temperature is allowed within the range of 55° F to 32° F.

(i) These allowable increases apply to all waters in the state classified B-3, except for the mainstem of the Yellowstone River from the Billings water supply intake to the water diversion at Intake, where a 3° F maximum increase above naturally occurring water temperature is allowed within the range of 32° F to 79° F; within the range of 79° F to 81.5° F, no thermal discharge is allowed which will cause the water temperature to exceed 82° F; and where the naturally occurring water temperature is 81.5° F or greater, the maximum allowable increase in water temperature is 0.5° F.

(ii) From the water diversion at Intake to the North Dakota state line, a 3° F maximum increase above naturally occurring water temperature is allowed within the range of 32° F to 82° F; within the range of 82° F to 84.5° F, no thermal discharge is allowed which will cause the water temperature to exceed 85° F; and where the naturally occurring water temperature is 84.5° F or greater, the maximum allowable increase in water temperature is 0.5°F.

(f) No increases are allowed above naturally occurring concentrations of sediment, settleable solids, oils, or floating solids which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.

(g) True color must not be increased more than five units above naturally occurring color.

(h) Concentrations of toxic or other deleterious substances which would remain in the water after conventional water treatment must not exceed the maximum contaminant levels set forth in the 1975 National Interim Primary Drinking Water Standards (40 CFR Part 141) or subsequent revisions or the 1979 National Secondary Drinking Water Standards (40 CFR Part 143). The maximum allowable concentrations of toxic or deleterious substances also must not exceed acute or chronic problem levels as revealed by bio-assay or other methods. The values listed in Quality Criteria for Water published by the Office of Water and Hazardous Materials, EPA, Washington, D.C. (The Red Book) shall be used as a guide to determine problem levels unless local conditions make these values inappropriate. In accordance with section 75-5-306(1), MCA, it is not necessary that wastes be treated to a purer condition than the natural condition of the receiving water.

(i) The board hereby adopts and incorporates by reference 40 CFR Part 141, which sets forth the 1975 National Interim Primary Drinking Water Standards, and 40 CFR Part 143, which sets forth the 1979 National Secondary Drinking Water Standards. Copies of 40 CFR Part 141 and 40 CFR Part 143 may be obtained from the Water Quality Bureau, Department of Health and Environmental Sciences, Cogswell Building, Capitol Station, Helena, Montana, 59620. (History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80; AMD, 1982 MAR p. 1746, Eff. 10/1/82.)

16.20.621 C-1 CLASSIFICATION (1) Waters classified C-1 are suitable for bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.

(2) For waters classified C-1 the following specific water quality standards shall not be violated by any person:

(a) During periods when the daily maximum water temperature is greater than 60° F., the geometric mean number of organisms in the fecal coliform group must not exceed 200 per 100 milliliters, nor are 10 percent of the total samples during any 30-day period to exceed 400 fecal coliforms per 100 milliliters.

(b) Dissolved oxygen concentration must not be reduced below 7.0 milligrams per liter.

(c) Induced variation of hydrogen ion concentration (pH) within the range of 6.5 to 8.5 must be less than 0.5 pH unit. Natural pH outside this range must be maintained without change. Natural pH above 7.0 must be maintained above 7.0.

(d) The maximum allowable increase above naturally occurring turbidity is 5 nephelometric turbidity units except as permitted in ARM 16.20.631 through 16.20.635 and ARM 16.20.641 and 16.20.642.

(e) A 1° F maximum increase above naturally occurring water temperature is allowed within the range of 32° F to 66° F; within the naturally occurring range of 66° F to 66.5° F, no discharge is allowed which will cause the water temperature to exceed 67° F; and where the naturally occurring water temperature is 66.5° F or greater, the maximum allowable increase in water temperature is 0.5° F. A 2° F per hour maximum decrease below naturally occurring water temperature is allowed when the water temperature is above 55° F, and a 2° F maximum decrease below naturally occurring water temperature is allowed within the range of 55° F to 32° F.

(f) No increases are allowed above naturally occurring concentrations of sediment, settleable solids, oils, or floating solids, which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.

(g) True color must not be increased more than five units above naturally occurring color.

(h) Concentrations of toxic or deleterious substances must not exceed levels which render the waters harmful, detrimental or injurious to public health. The maximum allowable concentrations of toxic or deleterious substances also must not exceed acute or chronic problem levels as revealed by bioassay or other methods. The values listed in Quality Criteria for Water published by the Office of Water and Hazardous Materials, EPA, Washington, D.C. (The Red Book) shall be used as a guide to determine problem levels unless local conditions make these values inappropriate. In accordance with section 75-5-306(1), MCA, it is not necessary that wastes be treated to a purer condition than the natural condition of the receiving water.

(i) In the segment of the Clark Fork River classified C-1, the parameter limits set forth below apply rather than the limits listed for these parameters in the Red Book:

Parameter	Maximum Instantaneous Concentration ug/l
Total copper	90
Total zinc	300
Total iron	1300
Total lead	100
Total cadmium	10
Total arsenic	50
Total mercury	1

(History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80; AMD, 1982 MAR p. 1746, Eff. 10/1/82.)

16.20.622 C-2 CLASSIFICATION (1) Waters classified C-2 are suitable for bathing, swimming and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.

(2) For waters classified C-2 the following specific water quality standards shall not be violated by any person:

(a) During periods when the daily maximum water temperature is greater than 60° F., the geometric mean number of organisms in the fecal coliform group must not exceed 200 per 100 milliliters, nor are 10 percent of the total samples during any 30-day period to exceed 400 fecal coliforms per 100 milliliters.

(b) Dissolved oxygen concentration must not be reduced below 7.0 milligrams per liter from October 1 through June 1 nor below 6.0 milligrams per liter from June 2 through September 30.

(c) Induced variation of hydrogen ion concentration (pH) within the range of 6.5 to 9.0 must be less than 0.5 pH unit. Natural pH outside this range must be maintained without change. Natural pH above 7.0 must be maintained above 7.0.

(d) The maximum allowable increase above naturally occurring turbidity is 10 nephelometric turbidity units except as permitted in ARM 16.20.631 through 16.20.635 and ARM 16.20.641 and 16.20.642.

(e) A 1° F maximum increase above naturally occurring water temperature is allowed within the range of 32° F to 66° F; within the naturally occurring range of 66° F to 66.5° F, no discharge is allowed which will cause the water temperature to exceed 67° F; and where the naturally occurring water temperature is 66.5° F or greater, the maximum allowable increase in water temperature is 0.5° F. A 2° F per hour maximum decrease below naturally occurring water temperature is allowed when the water temperature is above 55° F, and a 2° F maximum decrease below naturally occurring water temperature is allowed within the range of 55° F to 32° F.

(f) No increases are allowed above naturally occurring concentrations of sediment, settleable solids, oils, or floating solids which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.

(g) True color must not be increased more than five units above naturally occurring color.

(h) Concentrations of toxic or deleterious substances must not exceed levels which render the waters harmful, detrimental or injurious to public health. The maximum allowable concentrations of toxic or deleterious substances also must not exceed acute or chronic problem levels as revealed by bio-assay or other methods. The values listed in Quality Criteria for Water published by the Office of Water and Hazardous Materials, EPA, Washington, D.C. (The Red Book) shall be used as a guide to determine problem levels unless local conditions make these values inappropriate. In accordance with section 75-5-306(1), MCA, it is not necessary that wastes be treated to a purer condition than the natural condition of the receiving water.

(i) In the segment of the Clark Fork River classified C-2, the parameter limits set forth below apply rather than the limits listed for these parameters in the Red Book:

Parameter	Maximum Instantaneous Concentration ug/l
Total copper	90
Total zinc	300
Total iron	2200
Total lead	100
Total cadmium	10
Total arsenic	50
Total mercury	1

(History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80; AMD, 1982 MAR p. 1746, Eff. 10/1/82.)

16.20.623 E CLASSIFICATION (1) Waters classified E are suitable for agricultural and industrial water uses other than food processing.

(2) For waters classified E the following specific water quality standards shall not be violated by any person:

(a) During periods when the daily maximum water temperature is greater than 60° F., the geometric mean number of organisms in the fecal coliform group must not exceed 200 per 100 milliliters, nor are 10 percent of the total samples during any 30-day period to exceed 400 fecal coliforms per 100 milliliters.

(b) Dissolved oxygen concentration must not be reduced below 3.0 milligrams per liter.

(c) Hydrogen ion concentration must be maintained within the range of 6.5 to 9.5.

(d) No increase in naturally occurring turbidity is allowed which will or is likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.

(e) No increase in naturally occurring temperature is allowed which will or is likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.

(f) No increases above naturally occurring concentrations of sediment and settleable solids, oils, or floating solids are allowed which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.

(g) No increase above naturally occurring true color is allowed which will or is likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.

(h) Concentrations of toxic or deleterious substances, pathogens, pesticides and organic and inorganic materials including heavy metals must be less than those demonstrated to be deleterious to livestock or plants or to humans who may consume such livestock or plants or to adversely affect other indicated uses. (History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80; AMD, 1982 MAR p. 1746, Eff. 10/1/82.)

16.20.624 C-3 CLASSIFICATION (1) The quality of these waters is naturally marginal for drinking, culinary and food processing purposes, agriculture and industrial water supply; however, since no better quality of water is available for these uses, degradation which will impact established beneficial uses will not be allowed.

(2) For waters classified C-3 the following specific water quality standards shall not be violated by any person:

(a) During periods when the daily maximum water temperature is greater than 60° F., the geometric mean number of organisms in the fecal coliform group must not exceed 200 per 100 milliliters, nor are 10 percent of the total samples during any 30-day period to exceed 400 fecal coliforms per 100 milliliters.

(b) Dissolved oxygen concentration must not be reduced below 5.0 milligrams per liter.

(c) Induced variation of hydrogen ion concentration (pH) within the range of 6.5 to 9.0 must be less than 0.5 pH unit. Natural pH outside this range must be maintained without change. Natural pH above 7.0 must be maintained above 7.0.

(d) The maximum allowable increase above naturally occurring turbidity is 10 nephelometric turbidity units, except as permitted in ARM 16.20.631 through 16.20.635 and ARM 16.20.641 and 16.20.642.

(e) A 3° F maximum increase above naturally occurring water temperature is allowed within the range of 32° F to 77° F; within the range of 77° F to 79.5° F, no thermal discharge is allowed which will cause the water temperature to exceed 80° F; and where the naturally occurring water temperature is 79.5° F or greater, the maximum allowable increase in water temperature is 0.5° F. A 2° F per hour maximum decrease below naturally occurring water temperature is allowed when the water temperature is above 55° F, and a 2° F maximum decrease below naturally occurring water temperature is allowed within the range of 55° F to 32° F.

(f) No increases are allowed above naturally occurring concentrations of sediment, settleable solids, oils or floating solids, which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.

(g) True color must not be increased more than five units above naturally occurring color.

(h) Concentrations of toxic or other deleterious substances must not exceed levels which render the waters harmful, detrimental or injurious to public health. The maximum allowable concentrations of toxic or deleterious substances also must not exceed acute or chronic problem levels as revealed by bio-assay or other methods. The values listed in Quality Criteria for Water published by the Office of Water and Hazardous Materials, EPA, Washington, D.C. (The Red Book) shall be used as a guide to determine problem levels unless local conditions make these values inappropriate. In accordance with section 75-5-306(1), MCA, it is not necessary that wastes be treated to a purer condition than the natural condition of the receiving water. (History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80; AMD, 1982 MAR p. 1746, Eff. 10/1/82.)

Rules 16.20.625 through 16.20.630 reserved

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16.20.631 TREATMENT STANDARDS (1) The degree of waste treatment required to restore and maintain the quality of surface waters to the standards shall be based on the surface water quality standards and the following:

(a) The state's policy of nondegradation of existing high water quality as described in section 75-5-303, MCA;

(b) Present and anticipated beneficial uses of the receiving water;

(c) The quality and nature of the flow of the receiving water;

(d) The quantity and quality of the sewage, industrial waste or other waste to be treated; and

(e) The presence or absence of other sources of pollution on the same watershed.

(f) Duing periods when the maximum daily water temperature is less than 60° F., the instream fecal coliform concentrations shall be limited by the Department only when necessary to protect human health.

(2) Sewage must receive a minimum of secondary treatment as defined by EPA in accordance with requirements set forth in the Federal Water Pollution Control Act, 33 U.S.C. et seq. (Supp. 1973), as amended, and 40 CFR Part 133 and subsequent amendments. Copies of 40 CFR Part 133 and subsequent amendments may be obtained from the department.

(3) Industrial waste must receive, as a minimum, treatment equivalent to the best practicable control technology currently available (BPCTCA) as defined in 40 CFR Subchapter N and subsequent amendments. Copies of 40 CFR Subchapter N and subsequent amendments may be obtained from the department. In cases where BPCTCA is not defined by EPA, industrial waste must receive a minimum of secondary treatment or equivalent as determined by the department.

(4) For design of disposal systems, stream flow dilution requirements must be based on the minimum consecutive 7-day average flow which may be expected to occur on the average of once in 10 years. When dilution flows are less than the above design flow at a point discharge, the discharge is to be governed by the permit conditions developed for the discharge through the waste discharge permit program. If the flow records on an affected surface water are insufficient to calculate a 10-year 7-day low flow, the department shall determine an acceptable stream flow for disposal system design. The department shall determine the acceptable stream flow for disposal system design for controlling nitrogen and phosphorus concentrations. (History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80; AMD, 1982 MAR p. 1746, Eff. 10/1/82.)

16.20.632 OPERATION STANDARDS Owners and operators of water impoundments operating prior to July 1971 that cause conditions harmful to prescribed beneficial uses of state water shall demonstrate to the satisfaction of the department that continued operations will be done in the best practicable manner to minimize harmful effects. New water impoundments must be designed to provide temperature variations in discharging water that maintain or enhance the existing propagating fishery and associated aquatic life. As a guide, the following temperature variations are recommended: Continuously less than 40° F during the months of January and February, and continuously greater than 44° F during the months of June through September. (History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80.)

16.20.633 PROHIBITIONS (1) State surface waters must be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will:

(a) Settle to form objectionable sludge deposits or emulsions beneath the surface of the water or upon adjoining shorelines;

(b) Create floating debris, scum, a visible oil film (or be present in concentrations at or in excess of 10 milligrams per liter) or globules of grease or other floating materials;

(c) Produce odors, colors or other conditions as to which create a nuisance or render undesirable tastes to fish flesh or make fish inedible;

(d) Create concentrations or combinations of materials which are toxic or harmful to human, animal, plant or aquatic life; and

(e) Create conditions which produce undesirable aquatic life.

(2) No wastes may be discharged and no activities conducted such that the wastes or activities, either alone or in combination with other wastes or activities, will violate, or can reasonably be expected to violate, any of the standards.

(3) No wastes are to be discharged and no activities conducted which, either alone or in combination with other wastes or activities, will cause violations of surface water quality standards; provided, a short term exemption from a surface water quality standard may be authorized by the department under the following conditions:

(a) If the Department of Fish, Wildlife and Parks reviews a short-term construction or hydraulic project under section 76-5-501 *et seq.*, MCA, or section 75-7-101 *et seq.*, MCA, an increase in turbidity caused by the project will be exempt from the applicable turbidity standard unless the department is advised by the Department of Fish, Wildlife and Parks that the project may result in a significant increase in turbidity. If the department is advised that the project may cause a significant increase in turbidity, the project will be exempt from the applicable turbidity standard only if it is carried out in accordance with conditions prescribed by the department in a 16.20.633(3) authorization.

(i) A 16.20.633(3) application form must be submitted to the department by the applicant and a 16.20.633(3) authorization issued by the department prior to the day on which the applicant commences the short-term construction or hydraulic project.

(b) If the department approves the location, timing, and methods of game fish population restoration authorized by the Department of Fish, Wildlife and Parks, restoration activities causing violations of surface water quality standards may be exempt from the standards.

(c) If a short-term activity other than those described in (a) and (b) above causes unavoidable short-term violations of the turbidity, total dissolved solids, or temperature standards, the activity is exempt from the standard if it is carried out in accordance with conditions prescribed by the department in a 16.20.633(3) authorization form.

(i) A 16.20.633(3) application form must be submitted to the department by the applicant and a 16.20.633(3) authorization issued by the department prior to the day on which the applicant commences the short-term activity.

(4) Leaching pads, tailing ponds or holding facilities utilized in the processing of ore must be located, constructed, operated and maintained in such a manner and of such materials so as to prevent the discharge, seepage, drainage, infiltration, or flow which may result in the pollution of surface waters. The department may require that a monitoring system be installed and operated if the department determines that pollutants are likely to reach surface waters or present a substantial risk to public health.

(a) Complete plans and specifications for proposed leaching pads, tailing ponds or holding facilities utilized in the processing of ore must be submitted to the department no less than 180 days prior to the day on which it is desired to commence their operation.

(b) Leaching pads, tailing ponds or holding facilities operating as of the effective date of this rule utilized in the processing of ore must be operated and maintained in such a manner so as to prevent the discharge, seepage, drainage, infiltration or flow which may result in the pollution of surface waters.

(5) Dumping of snow from municipal and/or parking lot snow removal activities directly into surface waters or placing snow in a location where it is likely to cause pollution of surface waters is prohibited unless authorized in writing by the department.

(6) Until such time as minimum stream flows are established for dewatered streams, the minimum treatment requirements for discharges to dewatered receiving streams must be no less than the minimum treatment requirements set forth in ARM 16.20.631(2) and (3).

(7) Treatment requirements for discharges to ephemeral streams must be no less than the minimum treatment requirements set forth in ARM 16.20.631(2) and (3). Ephemeral streams are subject to ARM 16.20.631 through 16.20.635 and ARM 16.20.641 and 16.20.642 but not to the specific water quality standards of ARM 16.20.615 through 16.20.624.

(8) Pollution resulting from storm drainage, storm sewer discharges, and non-point sources, including irrigation practices, road building, construction, logging practices, overgrazing and other practices must be eliminated or minimized as ordered by the department.

(9) Application of pesticides in or adjacent to state surface waters must be in compliance with the labeled direction, and in accordance with provisions of the Montana Pesticides Act (Title 80, Chapter 8, MCA) and the Federal Environmental Pesticides Control Act (7 U.S.C. 136 et seq. (Supp. 1973) as amended). Excess pesticides and pesticide containers must not be disposed of in a manner or in a location where they are likely to pollute surface waters.

(10) No pollutants may be discharged and no activities may be conducted which, either alone or in combination with other wastes or activities, result in the total dissolved gas pressure relative to the water surface exceeding 110 percent of saturation.

(11) On all public water supply watersheds, detailed plans and specifications for the construction and operation of logging roads will be submitted to the department for its approval as required by Title 75, Chapter 6, MCA. (History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80.)

16.20.634 MIXING ZONE Discharges to surface waters may be entitled a mixing zone which will have a minimum impact on surface water quality, as determined by the department. (History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80.)

16.20.635 SAMPLING METHODS Methods of sample collection, preservation and analysis used to determine compliance with the standards must be in accordance with the latest edition of Standard Methods for the Examination of Water and Wastewater published by the American Public Health Association or in accordance with tests or procedures that have been found to be equally or more applicable by EPA as set forth in 40 CFR 136 and subsequent amendments. Copies of 40 CFR 136 and subsequent amendments may be obtained at the department. (History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80.)

16.20.641 RADIOLOGICAL CRITERIA (1) No person shall cause radioactive materials in surface waters to:

(a) Be present in any amount which reflects failure in any case to apply all controls which are physically feasible;

(b) Exceed a concentration of 5 pCi/L of total Radium 226 plus Radium 228;

(c) Exceed a concentration of 8 pCi/L of total Strontium 90;

(d) Be present in the water or in sediments in amounts which could cause harmful accumulations of radioactivity in plants, wildlife, stock or aquatic life;

(e) Exceed the radiological limits established in the National Interim Drinking Water Standards (40 CFR Part 141) and subsequent amendments. Copies of the National Interim Drinking Water Standards and subsequent amendments may be obtained from the department. (History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80.)

16.20.642 BIOASSAY MEDIAN TOLERANCE CONCENTRATIONS Bioassay tolerance concentrations must be determined using the latest available research results for the materials, by bioassay tests procedures for simulating actual stream conditions as set forth in the latest edition of Standard Methods for the Examination of Water and Wastewater published by the American Public Health Association, ASTM Standards Part 31, or in accordance with tests or analytical procedures that are found to be equal or more applicable by EPA. Any bioassay studies made must be made using a representative sensitive local species and life stages of economic or ecological importance; provided other species whose relative sensitivity is known may be used when there is difficulty in providing the more sensitive species in sufficient numbers or when such species are unsatisfactory for routine confined bioassays. All bioassay methods and species selections must be approved by the department. (History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, 1980 MAR p. 2252, Eff. 8/1/80.)

16.20.643 METAL LIMITS IS REPEALED (History: Sec. 75-5-301 MCA; IMP, Sec. 75-5-301 MCA; Eff. 12/31/72; AMD, Eff. 11/4/73; AMD, Eff. 9/5/74; AMD, [REP], 1980 MAR p. 2252, Eff. 8/1/80.)

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APPENDIX 4b.

MONTANA DEPARTMENT OF HEALTH AND ENVIRONMENTAL SCIENCES
Environmental Sciences Division
Water Quality Bureau
Helena, Montana 59620

Administrative Rules of Montana
Title 16, Chapter 20 - Water Quality

Sub-Chapter 7 - NONDEGRADATION OF WATER QUALITY

Rule 16.20.701	Definitions
16.20.702	Applicability and Limitation of Surface Water Nondegradation -- General
16.20.703	Permit Conditions to Ensure Non-Degradation
16.20.704	Procedure for Petitioning for Amendments
16.20.705	Department and Board Procedures Following Receipt of Completed Petition

Sub-Chapter 7

Nondegradation of Water Quality

16.20.701 DEFINITIONS In this sub-chapter, the following terms have the meanings indicated below and are supplemental to the definitions set forth in section 75-5-103, MCA:

(1) (a) Except as provided in paragraph (b) of this subsection, "degradation" means that as a result of the activities of man:

(i) the level of coliform bacteria, dissolved oxygen, toxic and deleterious substances or radionuclides in surface water where quality is higher than the established water quality standards has become worse, or

(ii) an applicable water quality standard for hydrogen ion concentration (pH), turbidity, temperature, color, suspended solids or oils has been violated in surface water where quality is higher than the established water quality standards.

(b) (i) Changes in surface water quality resulting from nonpoint source pollutants from lands where all reasonable land, soil and water management or conservation practices have been applied are not considered degradation.

(ii) Temporary changes in surface water quality resulting from short-term construction or rehabilitation activities performed in accordance with ARM 16.20.633(3) are not considered degradation.

(iii) Changes in surface water quality which occur within a "mixing zone" as defined by ARM 16.20.603(8) are not considered degradation.

(2) "Montana pollutant discharge elimination system (MPDES)" means the system developed by the state of Montana for issuing permits for the discharge of pollutants from point sources into state waters, pursuant to ARM Title 16, Chapter 20, sub-chapter 9.

(3) "National resource waters" means all surface waters in national parks, wilderness or primitive areas.

(4) "New or enlarged point source" means a point source on which construction or major modification commenced or from which discharges increased on or after December 17, 1982. It does not include sources from which discharges have increased if the increase does not exceed the limits established in an existing MPDES permit for that source which was issued prior to December 17, 1982.

(5) "Nonpoint source" means a diffuse source of pollutants resulting from the activities of man over a relatively large area, the effects of which normally must be addressed or controlled by a management or conservation practice.

(6) "Surface waters" means any water on the earth's surface including, but not limited to, streams, lakes, ponds,

and reservoirs and irrigation drainage systems discharging directly into a stream, lake, pond, reservoir or other water on the earth's surface. Water bodies used solely for treating, transporting or impounding pollutants are not considered surface water for the purposes of this sub-chapter. (History: Sec. 75-5-201, 75-5-401, MCA; IMP, Sec. 75-5-303, 75-5-401, MCA; NEW, 1982 MAR p. 2141, Eff. 12/17/82.)

16.20.702 APPLICABILITY AND LIMITATION OF SURFACE WATER NONDEGRADATION -- GENERAL (1) The requirements of this sub-chapter apply to any activity of man which would cause a new or increased source of pollution to surface waters.

(2) If the board determines, based on necessary economic or social development, that degradation may be allowed, in no event may degradation of surface waters interfere with or become harmful, detrimental or injurious to public health, recreation, safety, welfare, livestock, wild birds, fish and other wildlife or other beneficial uses.

(3) Degradation of national resource waters is prohibited. (History: Sec. 75-5-201, 75-5-401, MCA; IMP, Sec. 75-5-303, MCA; NEW, 1982 MAR p. 2142, Eff. 12/17/82.)

16.20.703 PERMIT CONDITIONS TO ENSURE NON-DEGRADATION

(1) In issuing an MPDES permit to a new or enlarged point source, the department shall include conditions in the permit to ensure that the quality of receiving waters whose quality is higher than established water quality standards will not be degraded by the discharge of pollutants from the source.

(2) Conditions which may be imposed on an MPDES permit to ensure nondegradation of water quality include, but are not limited to:

(a) monitoring of water quality, both upstream and downstream of the point of discharge, with sufficient frequency to determine whether the quality of the receiving waters is being affected by the discharge;

(b) provisions for varying discharge levels, including periods of zero discharge if necessary, to assure maintenance of water quality. Variations in permitted discharge levels will be established to accommodate as closely as practicable the natural variations and fluctuations in the stream's flow and quality. Discharge levels may be established seasonally, adjusted continuously (based on a continuous monitoring program), or established in such other manner as the department deems most appropriate.

(3) In determining the appropriate frequency of monitoring and the appropriate adjustment in effluent discharge levels pursuant to this rule, the department shall consider the quality and beneficial uses of the receiving waters, the natural variations and fluctuations in the stream's flow and quality, the presence of other point sources,

and such other factors as the department deems relevant to the maintenance of water quality.

(4) Whenever an application for an MPDES permit is made for a new or enlarged point source which will be located downstream from a pre-existing point source for which an MPDES permit was issued prior to December 17, 1982, the baseline for determining the existing quality of the receiving waters will be that level of water quality which would be present from natural and non-point sources and from point sources for which MPDES permits were issued prior to December 17, 1982 in the absence of all new and enlarged point sources upstream from the receiving waters. The level used shall be that level which would exist if the existing permitted dischargers were discharging at the maximum levels allowed in their permits.

(5) The department shall impose conditions in MPDES permits sufficient to ensure that the baseline quality of receiving surface waters, as defined in subsection (4) of this rule, will not be degraded at any flow greater than the 7-day 10-year low flow for such waters. In those cases where the 7-day 10-year low flow is not known or cannot be calculated, the department shall determine an acceptable stream flow for disposal system design.

(6) Whenever after an MPDES permit has been issued continued monitoring reveals new or more accurate information about the natural quality and fluctuations of the receiving waters, and if such new information would justify the amendment of monitoring or discharge limitation provisions in the permit, the department may approve such a modification. The department shall follow the notice and hearing procedures set forth in ARM 16.20.905(4) - (10).

(a) The board hereby adopts and incorporates by reference ARM 16.20.905(4) - (10) which set forth procedures for public notice and public hearings on MPDES permit applications. Copies of ARM 16.20.905(4) - (10) may be obtained from the Water Quality Bureau, Department of Health and Environmental Sciences, Cogswell Building, Capitol Station, Helena, Montana, 59620. (History: Sec. 75-5-401 MCA; IMP, Sec. 75-5-303, 75-5-401, MCA; NEW, 1982 MAR p. 2142, Eff. 12/17/82.)

16.20.704 PROCEDURE FOR PETITIONING FOR AMENDMENTS

(1) If any condition which has been imposed on an MPDES permit requires the permittee to maintain the quality of receiving waters at levels better than the applicable water quality standards, the permittee may petition the board for a permit amendment as provided in this section. Such a petition must be filed within 30 days after the issuance of the MPDES permit. The procedures of this sub-chapter are also available to operators of pollution sources not subject to MPDES permit requirements.

(2) The petition must be filed with the board for its review and a copy concurrently submitted to the Water Quality Bureau of the department. The Water Quality Bureau shall submit copies of the petition to the Departments of Fish, Wildlife and Parks, State Lands, Agriculture, Commerce, and Natural Resources and Conservation, and the Environmental Quality Council.

(3) The department may require that a petition contain such of the following information as is warranted by the potential impacts of a proposed change in water quality and as will allow the board to determine whether the proposed change will preclude present and anticipated use of the affected waters and is justifiable as a result of necessary economic or social development:

(a) the proposed effluent limitation(s);

(b) a statement of reasons for the proposed effluent limitation(s);

(c) an analysis of the existing quality of the receiving water, including natural variations and fluctuations in the water quality parameter(s) for which an exemption from non-degradation conditions is requested;

(d) a complete description of the proposed development;

(e) an analysis of alternatives to the proposed effluent limitation(s) with justifications for not using alternatives that would result in no degradation or less degradation;

(f) an analysis of the quality of the proposed discharge;

(g) the distribution of existing flows and their expected frequency;

(h) an analysis demonstrating the expected stream quality for all alternatives;

(i) an analysis of the impacts of the proposed water quality changes on the present and future beneficial uses including any calculable monetary or other losses to the users;

(j) A showing that the change will not result in violations of water quality standards or preclude existing beneficial uses or diminish anticipated beneficial uses of the receiving waters;

(k) A detailed statement of economic or social need for the proposed development;

(l) A description of alternatives to the proposed development which would equally meet the economic or social need of the development but would not require water quality degradation;

(m) An analysis showing that the public would be better off with the development and lower quality water;

(n) a description and analysis of past, present and anticipated development in the area which justifies a change in water quality and use; including existing or anticipated residential, agricultural, industrial, natural resource or other developments; and explaining in each case why such developments are necessary, and why maintenance of existing water quality is no longer of optimum benefit to the public.

(4) The department shall notify the petitioner in writing within 30 days of receipt of a petition either that the petition contains the information the department has required pursuant to subsection (3) and is completed, or if not, which information so required is missing and must be submitted for the petition to be deemed completed. (History: Sec. 75-5-401 MCA; IMP, Sec. 75-5-303, 75-5-401, MCA; NEW, 1982 MAR p. 2144, Eff. 12/17/82.)

16.20.705 DEPARTMENT AND BOARD PROCEDURES FOLLOWING RECEIPT OF COMPLETED PETITION (1) No later than the next regularly scheduled board meeting after the petition is declared complete the board shall determine whether it will be necessary for the department to prepare an environmental impact statement.

(2) If the decision is made to prepare an EIS, the procedures of ARM 16.2.601 through 16.2.620 will apply. If a public hearing is held on the draft EIS pursuant to ARM 16.2.619, such hearing will be before the department.

(a) The board hereby adopts and incorporates by reference ARM 16.2.601 through 16.2.620 which are administrative rules establishing procedures for implementation of the Montana Environmental Policy Act and the preparation and review of environmental impact statements. Copies of ARM 16.2.601 through 16.2.620 may be obtained from the Water Quality Bureau, Department of Health and Environmental Sciences, Cogswell Building, Capitol Station, Helena, Montana, 59620.

(3) If the tentative decision is made not to prepare an EIS, the department's preliminary environmental review must be circulated to the public for a 30-day public comment period and the department shall submit a report and recommendation to the board.

(4)(a) If an environmental impact statement is prepared, the department shall submit its final environmental impact statement to the board no later than 180 days after the board's decision that an environmental impact statement is required, unless a public hearing on the draft environmental impact statement was held, in which case the deadline may be increased to 240 days.

(b) If no environmental impact statement is prepared, the department shall submit its report and recommendation to the board no later than 60 days after receipt of the completed petition.

(c) At the request of the department, the board may extend these deadlines whenever the size and complexity of the project or other special circumstances make extended review necessary.

(5)(a) At its next regularly scheduled meeting following the department's submission to the board pursuant to subsection (4), the board shall hold a public hearing on the petition, at which the board may receive oral and documentary evidence from the petitioner and the public. The petitioner will be entitled to present his evidence and submit rebuttal evidence, and the petitioner and the department may conduct such cross-examination as may be required, in the board's judgment, for a full and true disclosure of the facts.

(b) At least 30 days prior to that hearing, the department shall comply with the following:

(i) the "Public Notice Procedures" set forth in ARM 16.20.912; and

(ii) the "Distribution of Information" procedures set forth in ARM 16.20.913.

(c) The board hereby adopts and incorporates by reference ARM 16.20.912, which sets forth procedures for issuing public notices of MPDES permit applications and hearings, and ARM 16.20.913 which sets forth requirements for distribution and copying of public notices and permit applications. Copies of ARM 16.20.912 and 16.20.913 may be obtained from the Water Quality Bureau, Department of Health and Environmental Sciences, Cogswell Building, Capitol Station, Helena, Montana, 59620.

(6) No later than the next regularly scheduled board hearing following the public hearing on the petition, the board shall issue its final decision, accompanied by a statement of reasons stating the basis for the decision and explaining why an exemption from nondegradation is or is not justified. (History: Sec. 75-5-201, 75-5-401, MCA; IMP, Sec. 75-5-303, 75-5-401, MCA; NEW, 1982 MAR p. 2145, Eff. 12/17/82.)

Sub-Chapter 8 reserved

NEXT PAGE IS 16-983

ENDECO®

TYPE 2100 SEPTIC LEACHATE DETECTOR SYSTEM
(SEPTIC SNOOPER™)

FAST-ACCURATE-ECONOMICAL . . .

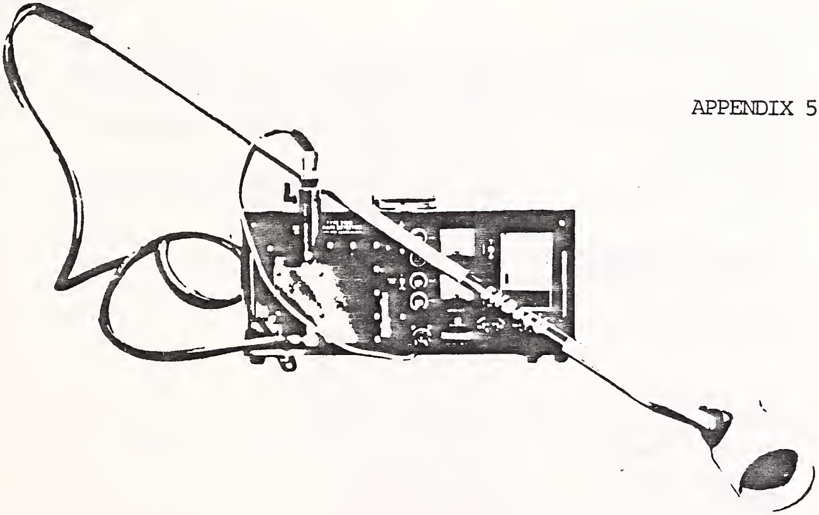
For pinpointing suspected septic leachate pollution where potable or recreational waters may become contaminated by local wastewater leaching.

APPLICATIONS INCLUDE . . .

- Locating septic leachate plumes in streams, lakes, rivers, reservoirs, or harbors.
- Detailed surveys of municipal waste treatment outfalls.
- On-line monitoring of sewage effluent discharges.

THE SEPTIC SNOOPER SYSTEM

APPENDIX 5.



FEATURES

Dual Channel Sensing
(Organics and Inorganics)
Two Speed Selectable Flow Rate
Analog Output
Multi-Range Conductivity Probe

12 VDC Operation
Rugged Stable Fluorometer
Valveless Submersible Pump
Corrosion Resistant
Portable

ENVIRONMENTAL DEVICES CORP., MARION, MASS., U.S.A. 02738

INTRODUCTION

The Type 2100 Septic Snooper System provides the answer to rapid pinpointing of suspected septic leachate plumes responsible for polluting lakes, ponds, and beaches affronting residential properties. With this portable field instrument, the operator is able to continuously scan an expansive shoreline at walking pace and, through real time feedback, effectively limit the need for discreet grab samples to areas showing high probability of effluent leaching. Expensive laboratory time for detailed nutrient analysis is greatly reduced while survey accuracy is increased substantially.

A domestic septic disposal system, under normal operations, creates a mass of bacteria and fungi immediately below the leaching zone. This zone will decompose the organics and fix nutrients found on the effluent. A septic leachate problem results from an overloaded septic system where:

- increased rate of flow of waste water does not allow sufficient time for breakdown of organic residues. Certain characteristics of the organic residues then appear downstream.
- lowered oxygen condition and the reduced soil adsorption capacity leads to inorganic breakthrough of ammonia nitrogen (NH^4-N) and phosphorous (P).

SEPTIC LEACHATE DETECTION

The capillary-like structure of porous soils and horizontal ground-water movement induces a narrow leachate plume from malfunctioning septic systems. The point of discharge along the shoreline is often through a small area of lake bottom, commonly forming an oval-shaped area of perhaps 1 m wide and 2 m long when the septic unit is close to the shoreline. In a denser subdivision containing several malfunctioning units, the discharges may overlap, sometimes resulting in a broad background increase.

The organic residuals of septic leachate discharges will fluoresce when correctly stimulated. Inorganics, dominated by chloride (Cl^-) and sodium (Na^+), provide a relative change in conductivity of water when compared to nearby unaffected water. By monitoring both of these characteristics of septic leachate, a leachate plume can be detected along a shoreline.

DETAILED

ORGANIC CHANNEL:

Sensor Type:	Flow through fluorometer
Range:	0 to 100 when calibrated with 10% ENDECO Type 934 Effluent Standard
Repeatability:	±5% of Full Scale at constant temperature
Resolution:	1% of Full Scale
Detection Limit:	2% of Full Scale using ENDECO Type 934 Effluent Standard in freshwater
Controls:	Zero and Span

INORGANIC CHANNEL

Sensor Type:	Electrode type conductivity cell with temperature compensation to 25°C
Range Choice:	Low: 0-200 μmhos/cm Med: 0-2000 μmhos/cm High: 0-20000 μmhos/cm
Zero Offset:	Continuously variable
Maximum Meter Span:	10, 100 or 1000 μmhos/cm (adjustable)
Accuracy (sensor):	±5% of Full Scale
Resolution (meter):	1% of Full Scale
Detection Limit:	2% of Full Scale
Controls:	Zero, Span, and Polarity

RECORDER

Type:	Single channel Rustrak galvanometric strip chart recorder with striker bar
Writing Rate:	1 strike/sec.
Chart Speed:	25.4 cm (1 in/min)
Chart Width:	62 cm (2.8 in)
Chart Length:	18.3 m (60 ft)
Chart Type:	Pressure Sensitive
Function Selector:	1. Organic (0-100% of span, fluorescence) 2. Inorganic (0 to 100% of span, conductivity) 3. Combined (organic and inorganic)

OPERATION

Signal processing of dual parameter inputs correlates to relative effluent strength above ambient background. The submersible lift pump in the probe draws sample water from the bottom and passes it through a fluorometer unit which is sensitive to fluorescing organic molecules representative of laundry whiteners and septic wastes; then it passes through a graphite electrode type conductivity cell sensitive to inorganic content. The processed signal is recorded on paper tape for a permanent record. The instrument may be zeroed against most fresh pond or brackish waters, and standardized with a well characterized effluent material.

CONVENIENCE

The deck unit is lightweight and constructed with water resistant materials. It comes in an attractive carrying case with removable lid and soft rubber feet for protection of lab bench or deck surfaces. The unit operates in the vertical position, powered by a standard 12 volt automotive battery. It has rack handles for easy chassis removal during maintenance. The plug-in flow through conductivity cell is in series with the fluorometer section. The probe wand houses the durable sampling pump. Discrete samples may be drawn from the instrument discharge for subsequent laboratory analysis.

SPECIFICATIONS

OPERATING ENVIRONMENT

Operating Medium:	Salt, fresh, or brackish water
Operating Temp. Range:	+2° to 35°C (35.6° to 95°F)
Storage Temp. Range:	−40° to +65°C (−40° to +149°F) with instrument drained

SUBSURFACE SENSOR ASSEMBLY

Material:	PVC plastic
Hardware:	300 series stainless steel
Dimensions Sensor Head:	15.2 cm diameter x 20.3 cm long (6 in x 8 in)
Hose:	1.5 m x 25 cm O.D. (5 ft x 1 in)
Weight in Air:	4.5 kg (10 lb)
Handle:	1.8 m long x 3.2 cm O.D. (6 ft x 1.3 in)

DECK UNIT

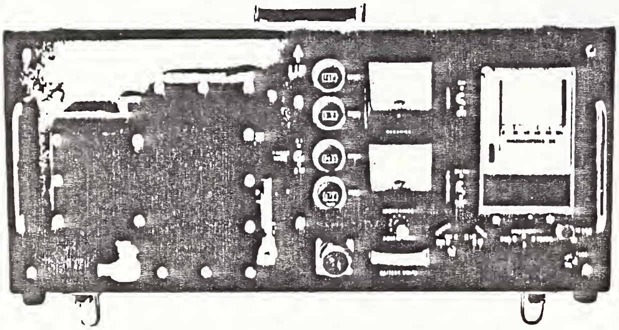
Material:	Corrosion resistant Formica case
Hardware:	300 series stainless steel and chrome plated brass
Dimensions:	25.4 cm x 35.6 cm x 57.2 cm (10 in x 14 in x 22.5 in)
Weight:	9 kg (20 lb)
Power (external):	12 VDC at 4 amp (11 to 15 VDC)
Battery Supply Meter:	0 to 15 VDC
Warm-up Period:	5 min.

SHIPPING DATA

Dimensions:	Box 1: 38.1 cm diameter x 2.1 m (15 in x 7 ft) Box 2: .46 m x .46 m x .91 m (1.5 ft x 1.5 ft x 3 ft)
Weight:	Box 1: 18.1 kg (40 lb) Box 2: 27.2 kg (60 lb)

THE SEPTIC SNOOPER™ SYSTEM

An ENDECO Water Quality Monitoring innovation . . .
Responding to the needs of our environment.



TYPE 2100 DECK UNIT
(DOES NOT SHOW
CONDUCTIVITY PROBE)

UNDERWATER UNIT
SHOWING
HEMISPHERICAL SCREEN.

For your water quality monitoring needs, contact:

Environmental Devices Corp.
Tower Building
Marion, Ma. 02738
Telephone: 617/748-0366 Telex: 929451

INTRODUCTION

Swanson Environmental, Inc. has been retained by Georgetown Lake/ Clean Lakes Project of Anaconda, Montana to conduct a septic leachate detection survey on Georgetown Lake, located in Deer Lodge/Granite Counties, 14 miles west of Anaconda, Montana. A map of the Georgetown Lake study area is illustrated in Figure 1. The location of Georgetown Lake in respect to local cities and in the State of Montana are illustrated in Figure 2. Objectives of the study were to locate septic leachate plumes entering Georgetown Lake to assess the potential for environmental and human health problems associated with such discharge.

During the septic leachate study at Georgetown Lake, 7.76 miles of shoreline were surveyed. The areas of shoreline to be studied were selected by Mr. Paul Garrett, project scientist for the EPA Georgetown Lake Clean Lakes project. The septic leachate survey was conducted on July 6-8, 1981, by Mr. James Yanko of Swanson Environmental and Mr. Paul Garrett, project scientist.

PROCEDURES

One cause of increasing lake eutrophication is malfunctioning domestic septic systems on lake shores which release nutrients and bacteria into lake water through bottom sediments. Septic seepage results from several conditions including: (1) shallow groundwater encouraging soil water saturation and anaerobic conditions, (2) location too near the waters edge to allow complete bacterial degradation and soil adsorption of potential contaminants, and (3) overcrowding of homes causing hydraulic overloading of good systems or poorly designed systems due to excessive use during peak recreation periods. When any of these conditions exist, septic leachate can be carried along with the groundwater, erupting as an active plume along the lake bottom.

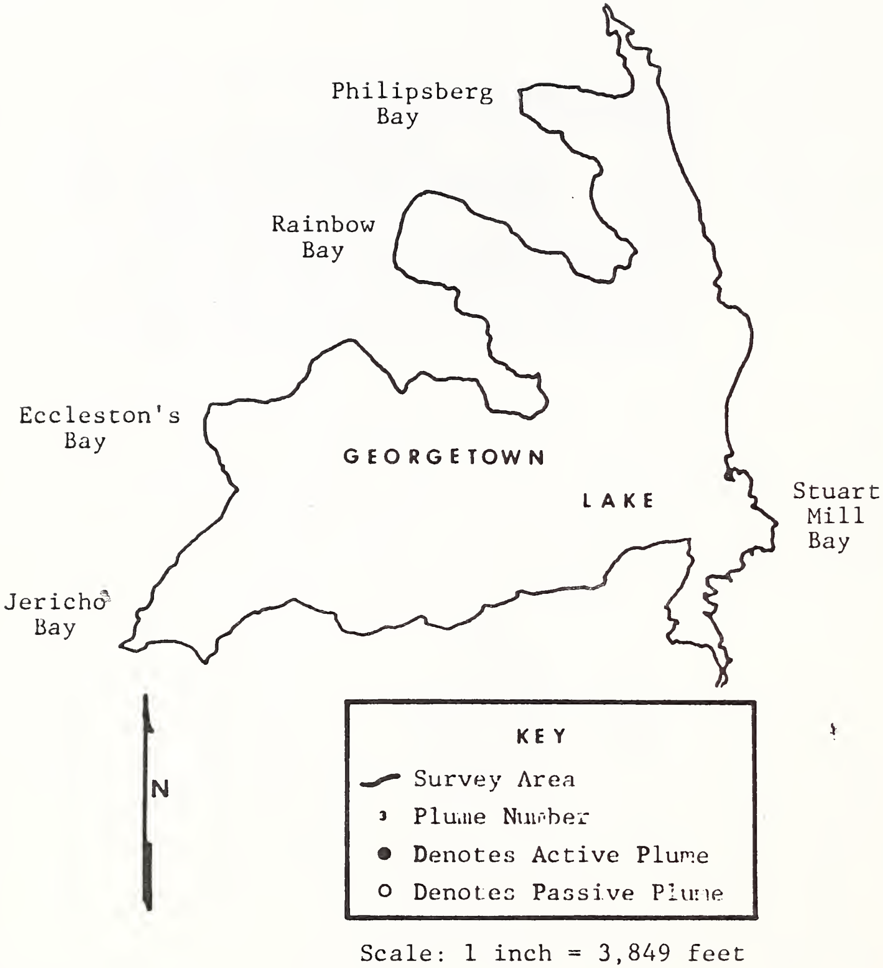


Figure 1. Georgetown Lake, septic leachate survey site, July 6-8, 1981.

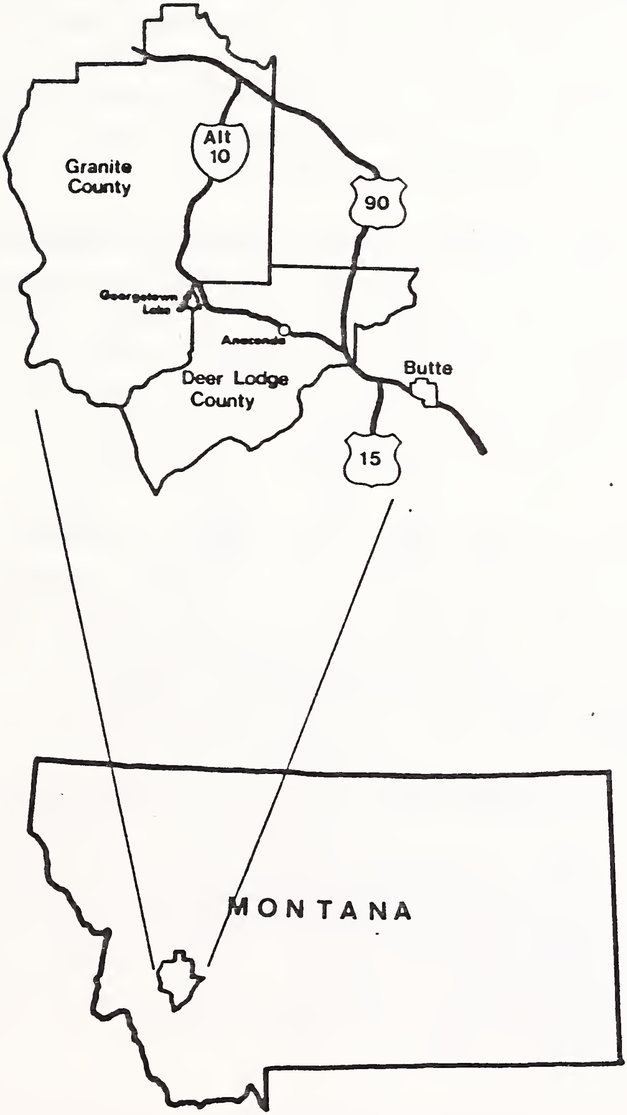


Figure 2. Location of Georgetown Lake in respect to local cities and in the State of Montana.

Figure 3 illustrates how a typical septic system might fail and discharge pollutants into a lake. Discharges generally travel horizontally with the groundwater flow, entering the lake in shallow shoreline areas. Such a discharge may be classified as an actively erupting or passive subsurface plume. Contamination may also result from direct surface runoff.

Septic leachate contains both UV fluorescent organics and conductive inorganics. Whiteners, surfactants, and natural degradation products fluoresce in the UV range. Inorganics such as chlorides and sodium contribute to electrical conductivity. A stable ratio exists between fluorescence and conductivity, with increased levels of both found in the vicinity of active leachate plumes.

Passive leachate plumes occur where septic systems have been in disuse, as during winter months for a summer residence or when groundwater levels fluctuate causing intermittent septic discharge. Passive plumes are indicated by high fluorescence and normal levels of conductivity. This condition is caused by the persistence of organic materials which continue to be released from the sediments for up to six months after active discharge. Inorganics are highly mobile and quickly dissipate once the source is removed.

Evaluation of septic leachate on Georgetown Lake consisted of identification of leachate plumes which can be verified by chemical analysis of subsurface water samples.

The septic leachate detection survey was performed using an ENDECO Septic Snooper ™ Model 2100 to identify leachate plumes entering Georgetown Lake. The detector is a portable unit which continuously measures fluorescence and conductivity of water passing through the instrument. Sample water is drawn from the lake through an attached submersible pump, scanned, and discharged back into the lake. The pump is mounted on a long handled probe

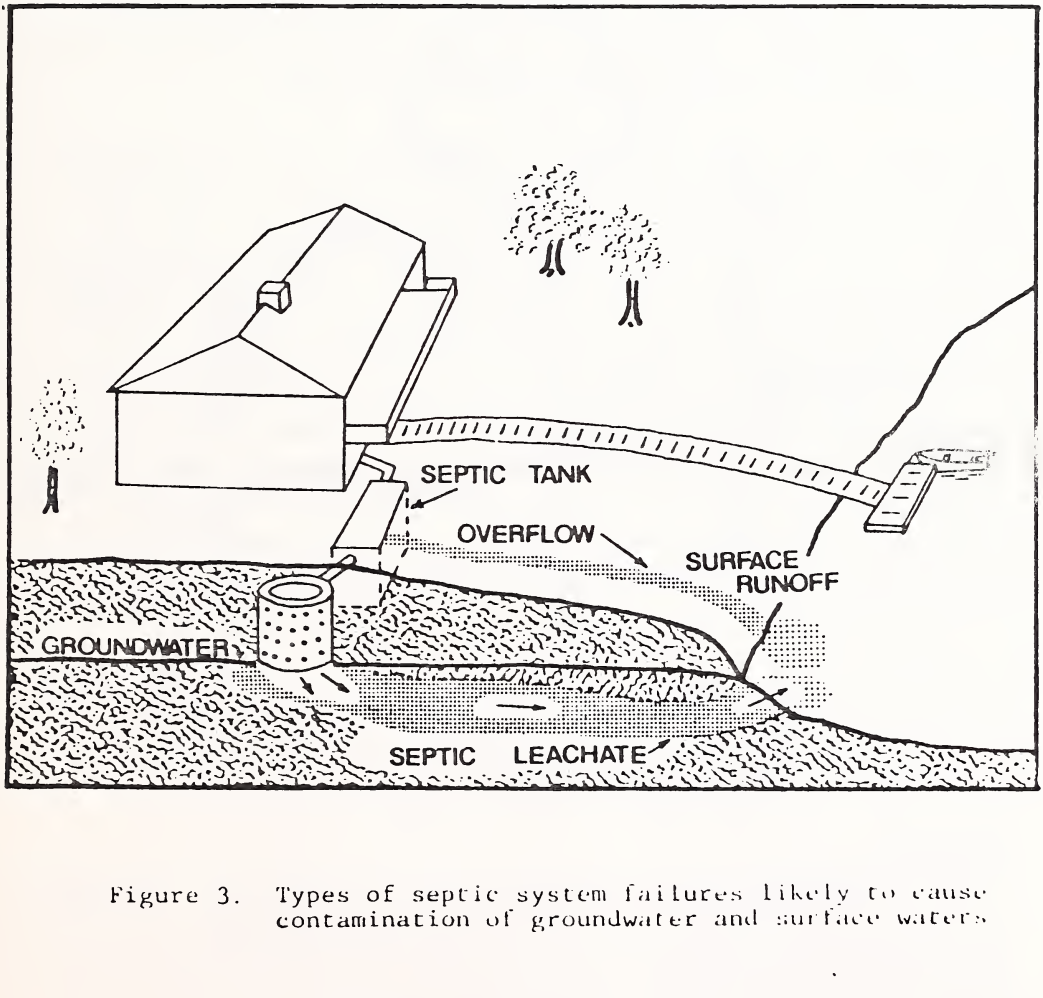


Figure 3. Types of septic system failures likely to cause contamination of groundwater and surface waters

to facilitate sampling bottom water where plumes are most likely to occur.

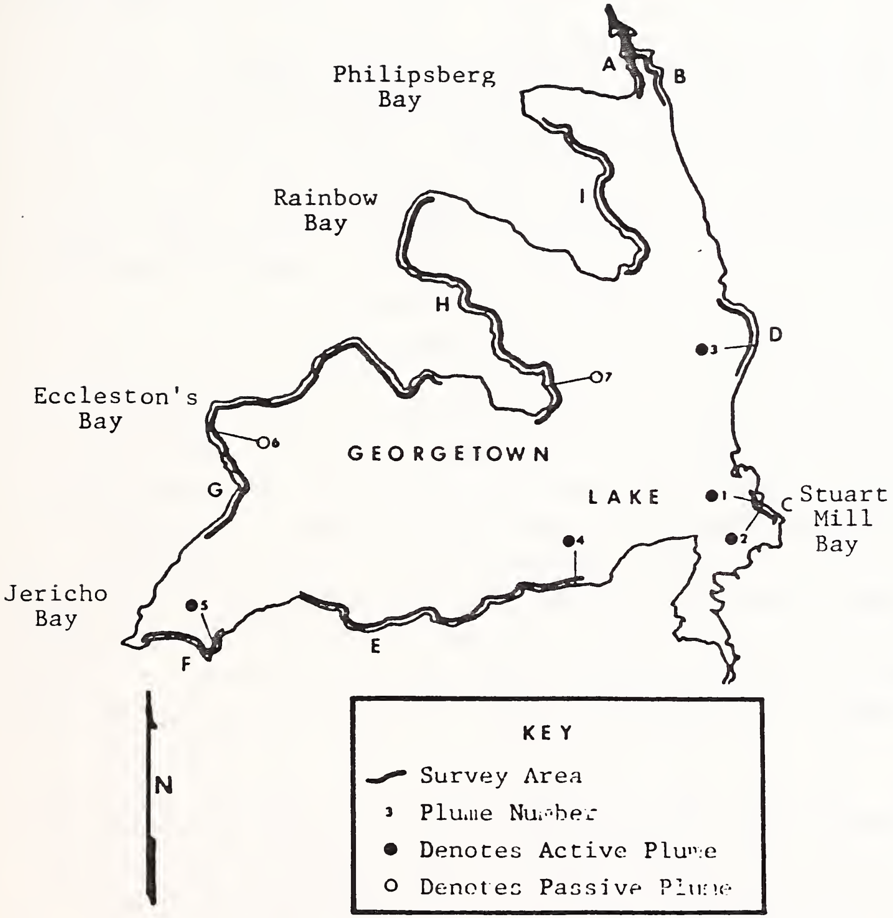
Immediately preceding the survey, the leachate detector was calibrated to local conditions using secondary effluent diluted with lake water taken from an offshore sample. Such calibration is required to account for local effluent characteristics and background water quality, specifically, natural fluorescence and conductivity. Calibration procedures and equipment operating parameters are included in Appendix A.

The survey was executed using a sixteen-foot jon boat equipped with an electric motor to maneuver survey personnel and equipment slowly along the shoreline. During the survey, the boat and probe were kept within 15 - 20 feet of the actual shoreline to effectively sample likely plume areas. The sample probe was positioned in 1 - 2 feet of water, continuously drawing water from within one foot of the lake bottom. As sample water was scanned, a continuous graphic output was recorded and septic leachate plumes were noted on large scale shoreline maps. When significant increases in fluorescence and conductivity were observed, the vicinity was scanned to determine the point of maximum plume concentration and a single surface water sample was collected from the leachate detector discharge hose.

The surface water sample, collected from one active plume site on Georgetown Lake, was placed in a polyethylene container for transport to the laboratory located in Anaconda, Montana.

RESULTS

A summary of the survey area and septic leachate plume locations are presented in Figure 4. Strip chart recordings of background water quality and septic leachate plumes encountered during the survey are included in Appendix B.



Scale: 1 inch = 3,839 feet

Figure 4. Locations of septic leachate survey areas including passive and active plumes in Georgetown Lake. July 6-8, 1981.

Locations of Septic Leachate Plumes

A total of seven (7) septic leachate plumes were identified during the Georgetown Lake survey. These include five (5) active plumes and two (2) passive plumes. In addition, three locations showed signs of contributing septic leachate, however, either dense concentrations of pollen, algae or heavy macrophyte growth prevented positive identification.

The positive septic leachate plumes were located in areas C (2) (numbers 1 and 2), D (1) (number 3), E (1) (number 4), and F (1) (number 5). The passive plumes were located in areas G (1) (number 6) and H (1) (number 7), Figure 3. The two (2) positive plumes, numbers 1 and 2, in Area C are located on either side of the small peninsula on which Stuart's Landing is located. The single positive plume in Area D, number 3, is most likely the subsurface entrance of the culvert which drains the marsh at the intersection of Highway 10 A and Echo Lake Road. The single positive plume in Area E, number 4, was located at the first cabin (the survey was conducted from north to south). The single positive plume found in Area F, number 5, was in front of a small red cabin with a rust colored boat house in Jericho Bay. A single water sample was collected here for analyses in Anaconda, Montana.

A single inactive plume was found in Area G, number 6. This was being emitted from a culvert near a resort located in Eccleston's Bay. In Area H, a single inactive plume, number 7, was located adjacent to a red cabin which had a green roof and brown boathouse. In this area the water was very clear and no rooted macrophytes or heavy concentrations of algae of pollen were evident. The cabin did not appear to be occupied.

The other areas of concern are located in the bay formed by the Dam and spillway. These include small secluded bays on both the north and south side of the bay. These small bays showed increases in organics and had cabins located in low areas adjacent to the shoreline. They also contained heavy growths of macrophytes and dense concentrations of algae and pollen which made positive identification of passive plumes inconclusive. No increase in conductivity was noted at these sites.

CONCLUSIONS

The septic leachate survey conducted on Georgetown Lake has identified five active plumes and two passive plumes in the major portion of the lake. These contributions have the potential for both ecological and human health problems because of the added nutrients to the ecosystem and possible exposure to human pathogens.

APPENDIX A

April 25, 1980

ENDECO* TYPE 2100
SEPTIC LEACHATE DETECTOR SYSTEM
(SEPTIC SNOOPER**)

OPERATION MANUAL

Environmental Devices Corp.
Tower Building
Marion, Ma. 02738

*Reg. U.S. Pat. Off.
**TM

I. INTRODUCTION

This unique monitoring system was developed by Environmental Devices Corporation in response to a need for an economical means of locating areas of septic system and sewage effluent discharges entering streams, lakes, rivers, reservoirs and harbors. It is a portable field unit that can be operated continuously to scan expansive shorelines in a comparatively short period of time. Real time feedback provides on-site determination of problem areas.

II. WASTEWATER PLUMES

The capillary-type structure of porous soils and the horizontal movement of groundwater induces a narrow leachate plume from malfunctioning septic systems. The point of discharge along the shoreline is often through a small area of lake bottom, commonly forming an oval-shaped area of several meters wide when the septic unit is close to the shoreline. In a denser subdivision containing several malfunctioning or overloaded systems, the discharges may overlap forming a broader background increase. Several different types of wastewater plumes may be encountered during a SEPTIC-SNOOPER survey: erupting plumes, dormant plumes, stream source plumes, and runoff plumes.

When soil becomes saturated with dissolved solids and organics during the aging process of an on-lot septic system, the eventual result is a breakthrough of organics followed by inorganics such as chloride and sodium. An erupting plume is an active emergence of the combined organic and inorganic residues into nearshore lake waters.

Where seasonal population fluctuates, wastewater loads will vary accordingly. Plumes that are evident during late summer may retreat during winter months when low flow conditions exist. However, residual organics from wastewater often remain attached to soil particles in the area of a previously erupting plume. They release only slowly into the surrounding waters. Such a dormant plume indicates a previous breakthrough, but sufficient treatment of the plume exists under such conditions so that no inorganic discharge is apparent.

Stream source plumes may be evident in situations where nearstream septic leaching fields enter a stream which eventually feeds into a lake.

In tight soil conditions where the rate of flow into a septic system exceeds the soil percolation, leakage often occurs around the septic tank or through the cover, creating standing pools of effluent. If sufficient surface drainage is present, the effluent may travel laterally across the surface and eventually reach nearby waters creating a runoff plume.

II. SYSTEM OPERATION

The SEPTIC-SNOOPER System monitors two parameters, fluorescence (organic channel) and conductivity (inorganic channel). The system is based on the theory that a stable ratio exists between fluorescence and conductivity in typical septic leachate outfalls. Readings for each channel appear visually on panel meters while the information is recorded on a self-contained strip chart recorder. Recording modes include individual channel outputs or a combined output.

The submersible lift pump in the probe draws water from the bottom and passes it through the fluorometer unit which is sensitive to fluorescing organic molecules from laundry whiteners, surfactants and natural degradation products. The water then passes through a graphite electrode type conductivity cell sensitive to inorganic ionic components such as chloride (Cl-) and sodium (Na+). Fluorescence and conductivity signals are generated and sent to an analog computer circuit that compares the signals against the background to which the instrument was calibrated. The resultant output is expressed as a percentage of the background and is continuously documented on the strip chart recorder. Full scale recorder output is provided for less than 1% septic leachate concentration. When higher than normal readings are encountered, discrete water samples can be taken directly from the instrument's discharge for later analysis of actual water quality. The system is powered by a standard 12 volt automobile battery or a portable generator. The system can be operated from a small boat moving at walking pace along shorelines or in fixed locations for static monitoring applications.

IV. PRESURVEY CALIBRATION AND FUNCTION CHECK

The following procedure is a field calibration procedure which should be performed prior to each survey.

1. Set organic and inorganic SPAN controls to "998".
2. Set organic and inorganic ZERO controls to "000".
3. Set SENSITIVITY to "NORM".
4. Set RANGE SCAN switch to "X 1".
5. Set function recording selector to "COMBINED".
6. Submerge pump unit in ambient water and turn power switch to "PUMP". Purge unit of all water from previous use, then turn power switch to "ON".
7. Remove pump unit from water and place in a container with 5 liters of ambient water drawn from the center of the lake or

water body. Be sure the discharge hose empties into the same container. Turn power switch to "PUMP" and recirculate water through the system.

8. Purge entire system of air bubbles by squeezing the intake hose several times. Allow the water to circulate for five minutes.
9. Adjust organic and inorganic ZERO controls to stabilize panel meters at a reading of "20".
10. Set CHART switch to "ON".
11. Depress NULL switch to set chart striker bar to zero.
12. Gently add 100 ml of standard effluent. Secondary treated effluent should be obtained from a sewage treatment facility in the approximate geographical area in which the survey is to be conducted. If no such effluent samples are obtainable, ENDECO Type 934 Standard Effluent may be used as an alternative.
13. Adjust organic and inorganic SPAN controls downward until panel meters read "100".
14. Record the final readings of SPAN and ZERO controls on each channel for later reference. The equipment calibration and function check is complete with this step and scanning may begin.

    CAUTION: Once calibration is complete do not remove pump from water; do not shut off power. Occurrence of either of the above may affect instrument sensitivity and may make recalibration necessary.

V. OPERATING PROCEDURE

Once calibration has been completed, the operation should proceed at a slow walking pace (1/2 nautical mile per hour) keeping the submerged pump just off the bottom. Distance from shore will vary as a function of water depth in most cases. Operating depth will normally be 1 to 5 feet depending on shoreline conditions and/or obstructions (natural or man-made). Proper distance and depth can in most cases be determined by a quick visual check of the area directly ahead of the operator.

VI. SAMPLING PROCEDURE

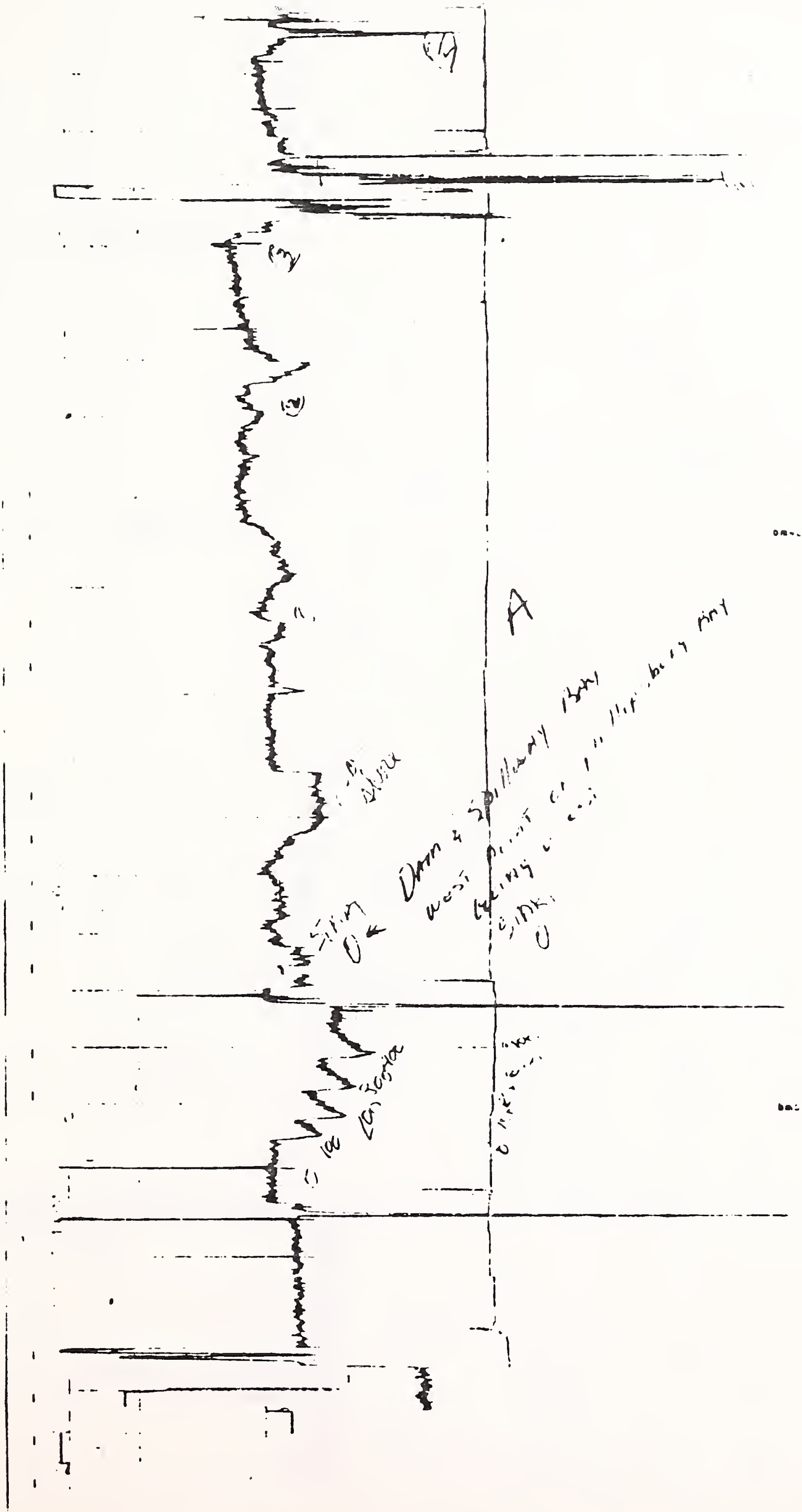
When significant simultaneous increases are detected, the operator should search the area to determine the point(s) of maximum concentration of both channels. This in turn will determine where grab samples should be taken.

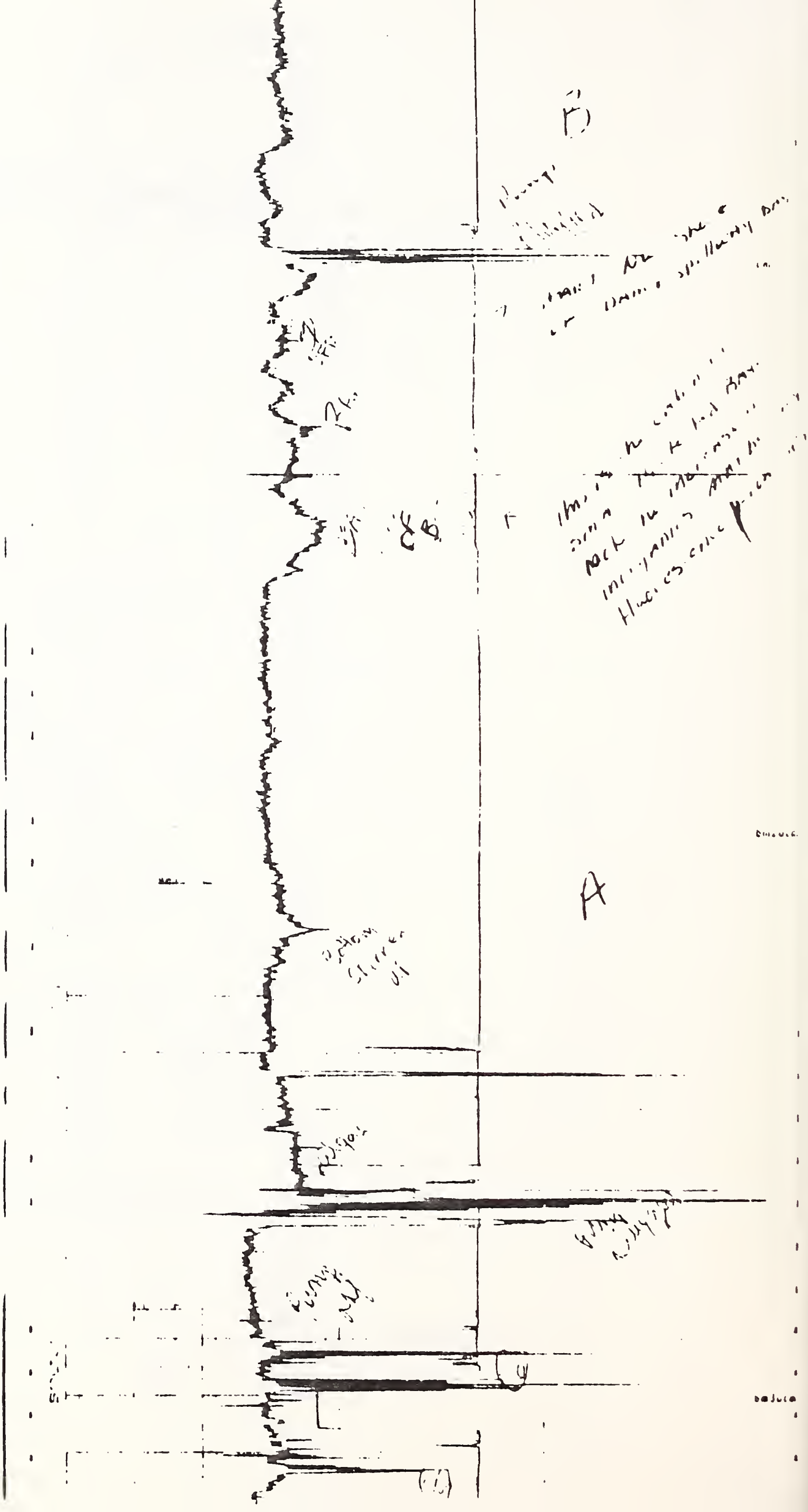
When significant single channel increases are detected, samples should also be taken at the point(s) of maximum concentration. In all cases, samples should be drawn from the system's discharge hose once the maximum possible readings have been obtained.

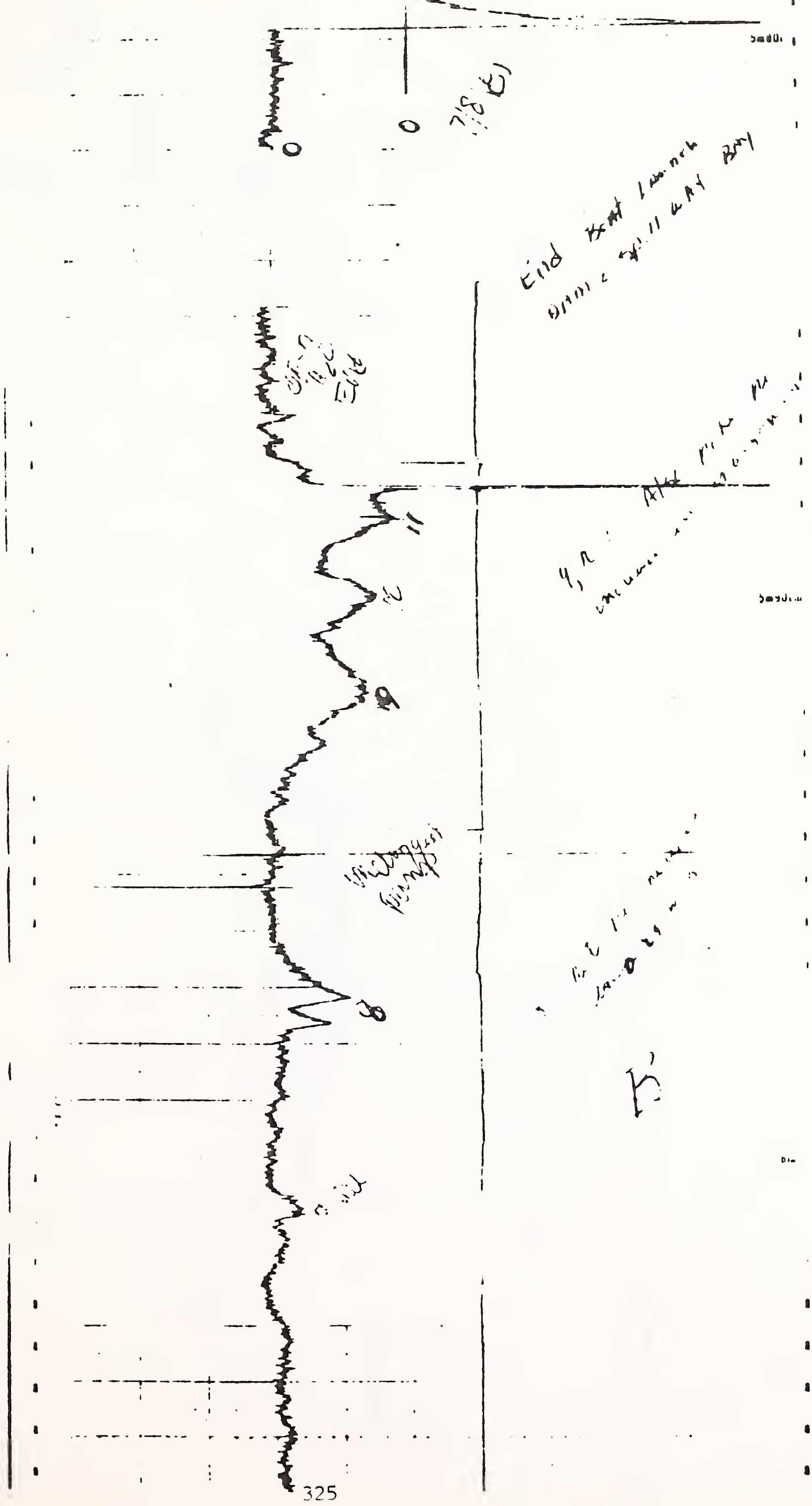
II. DOCUMENTATION

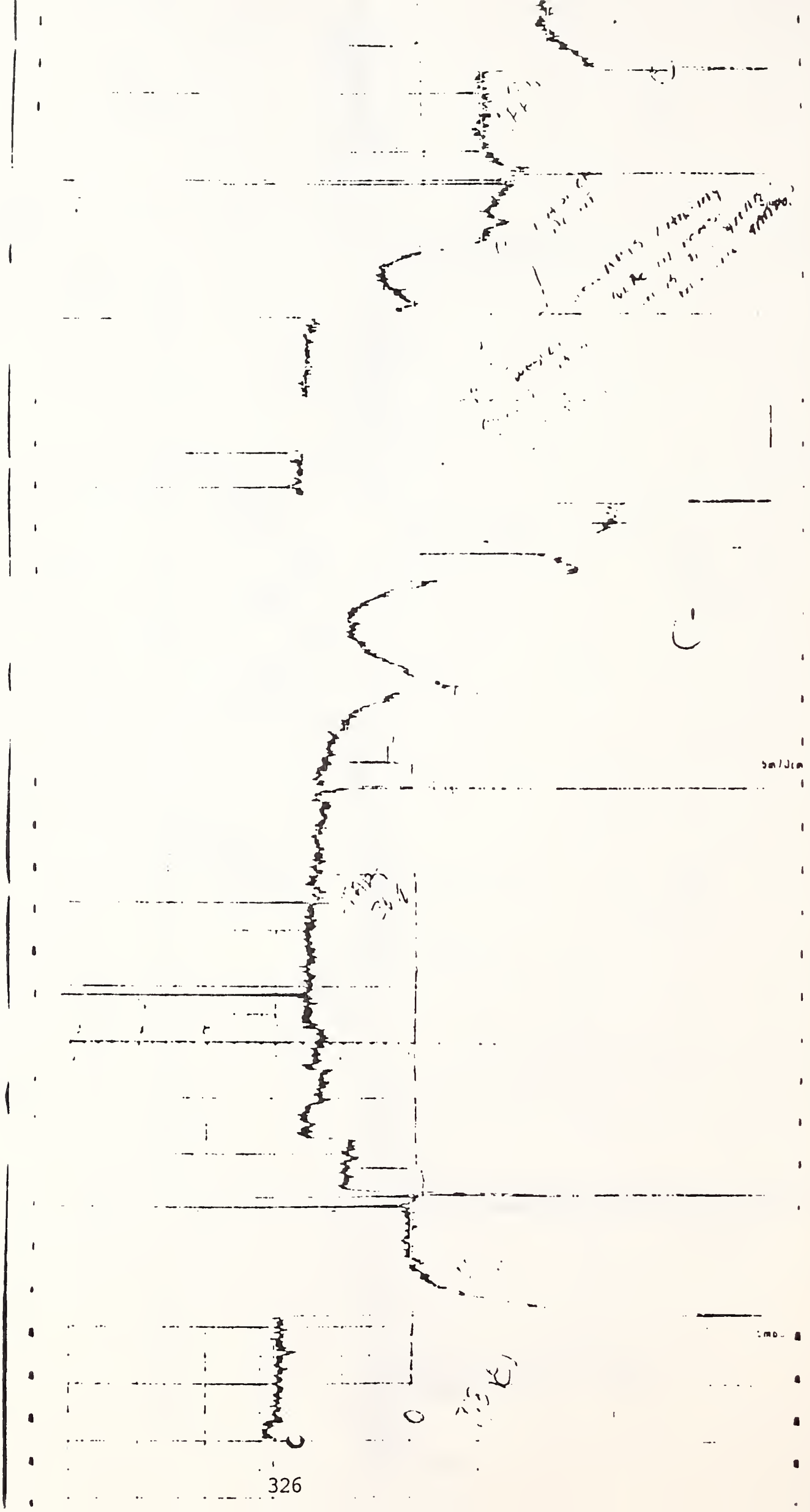
All significant information may be recorded on the strip chart during the course of the survey. This could include calibration settings, beginning and ending readings, sample locations, identifiable landmarks, instrument adjustments, etc. Field notes and/or cassette recordings may be necessary to complement the strip chart information in order to provide field reference data while the survey is in progress.

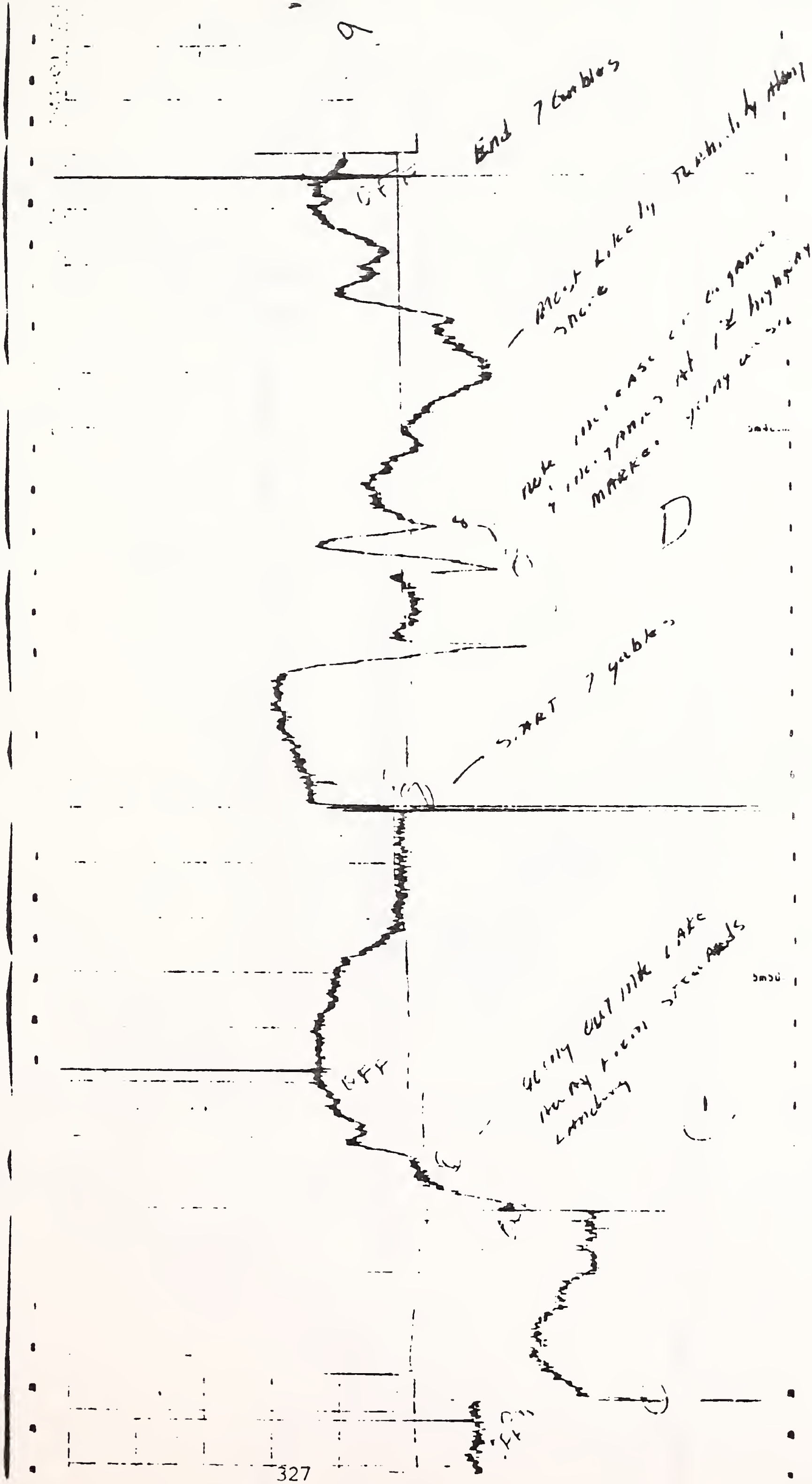
APPENDIX B

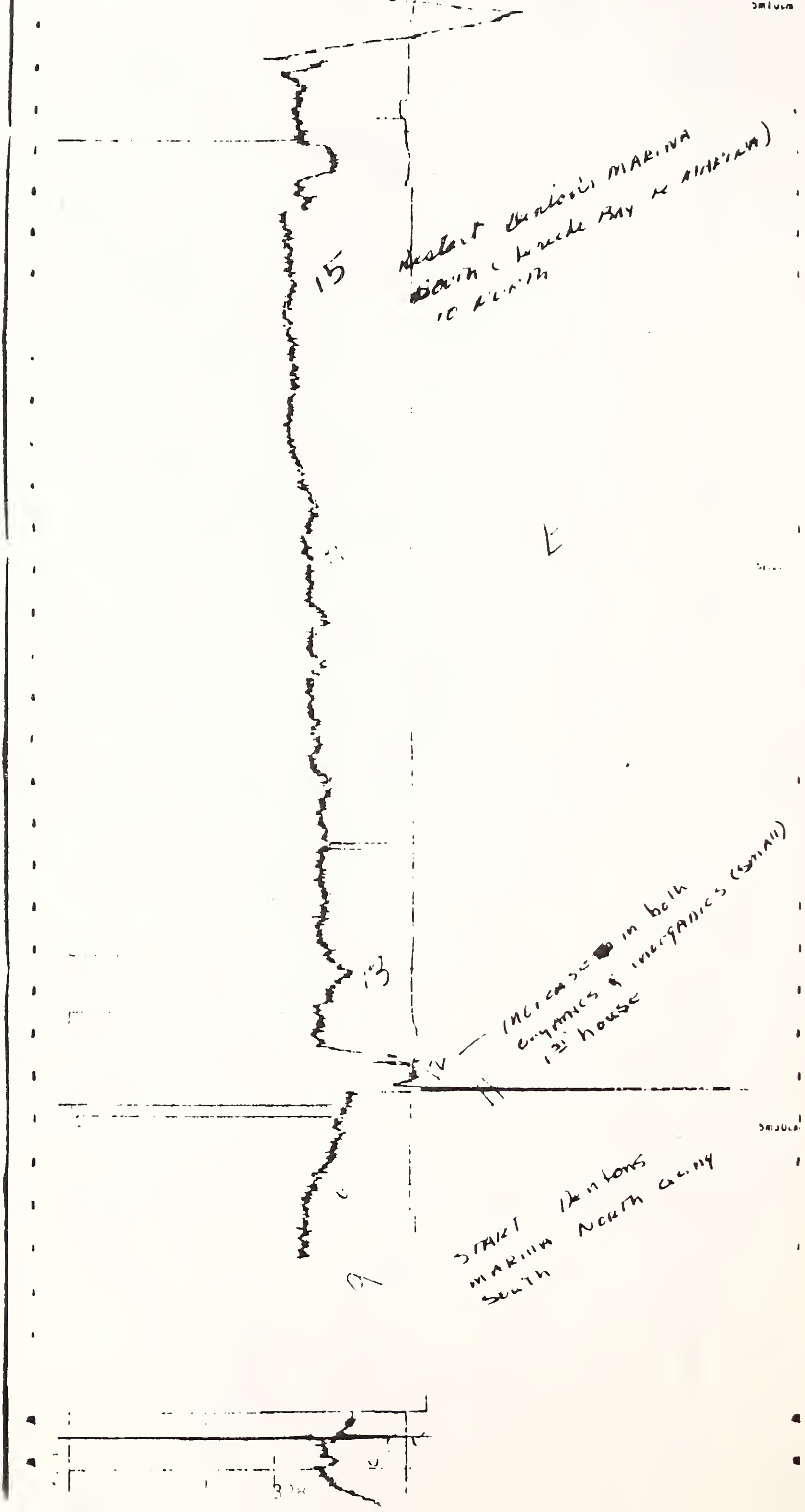

(5)
(4)
(3)
A
Dam & Spillway Bay
Stn 0
0 100 (m) Scale


B
A


0
0
End Boat launch
11
9
8



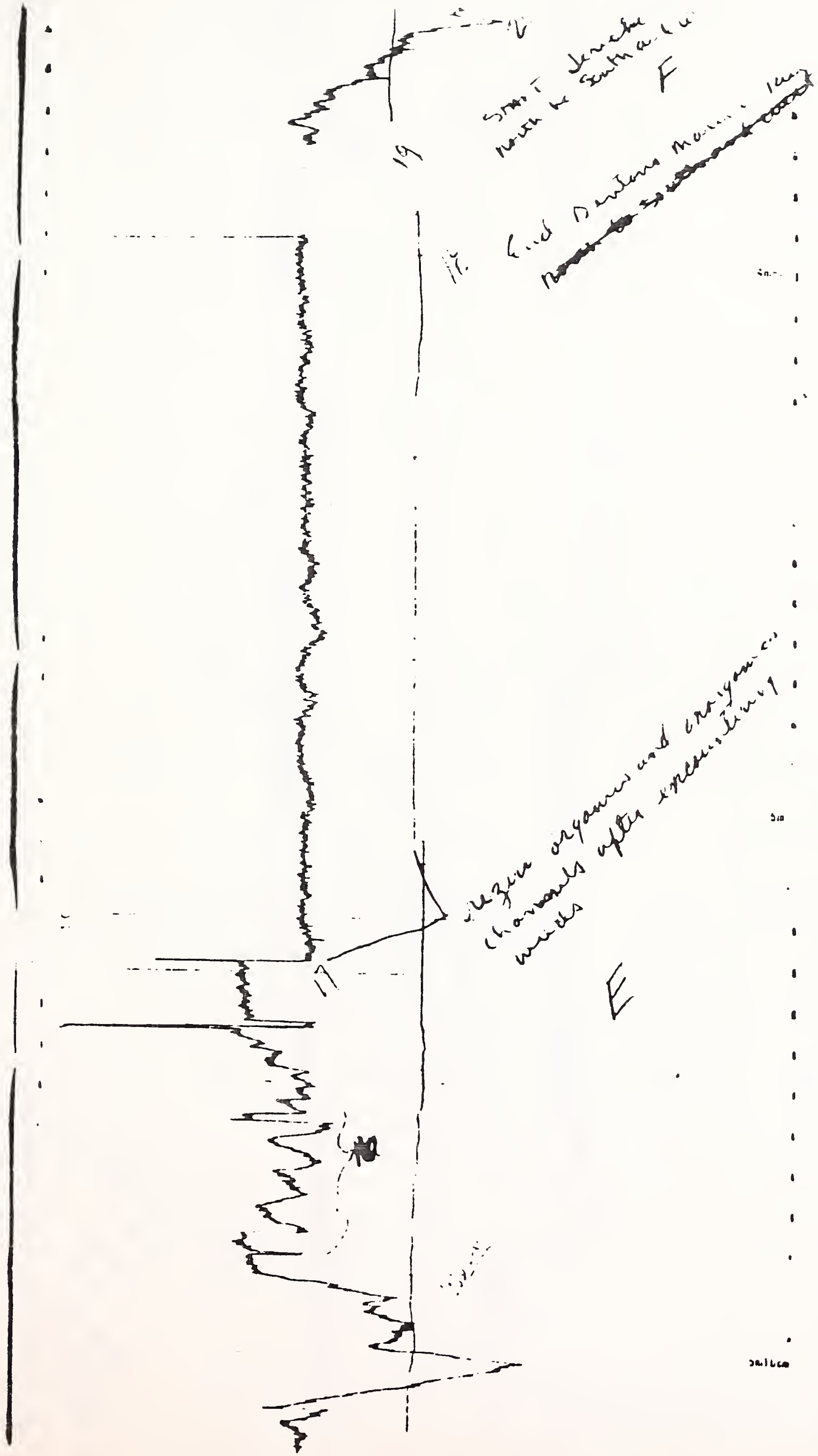

9
End 7 Gables
Most likely Turbidity along shore
Note increase in organics & inorganics at 1/2 highway marker going along
D
START 7 Gables
Going out into Lake through Front Street Landing
C
OFF
5m50

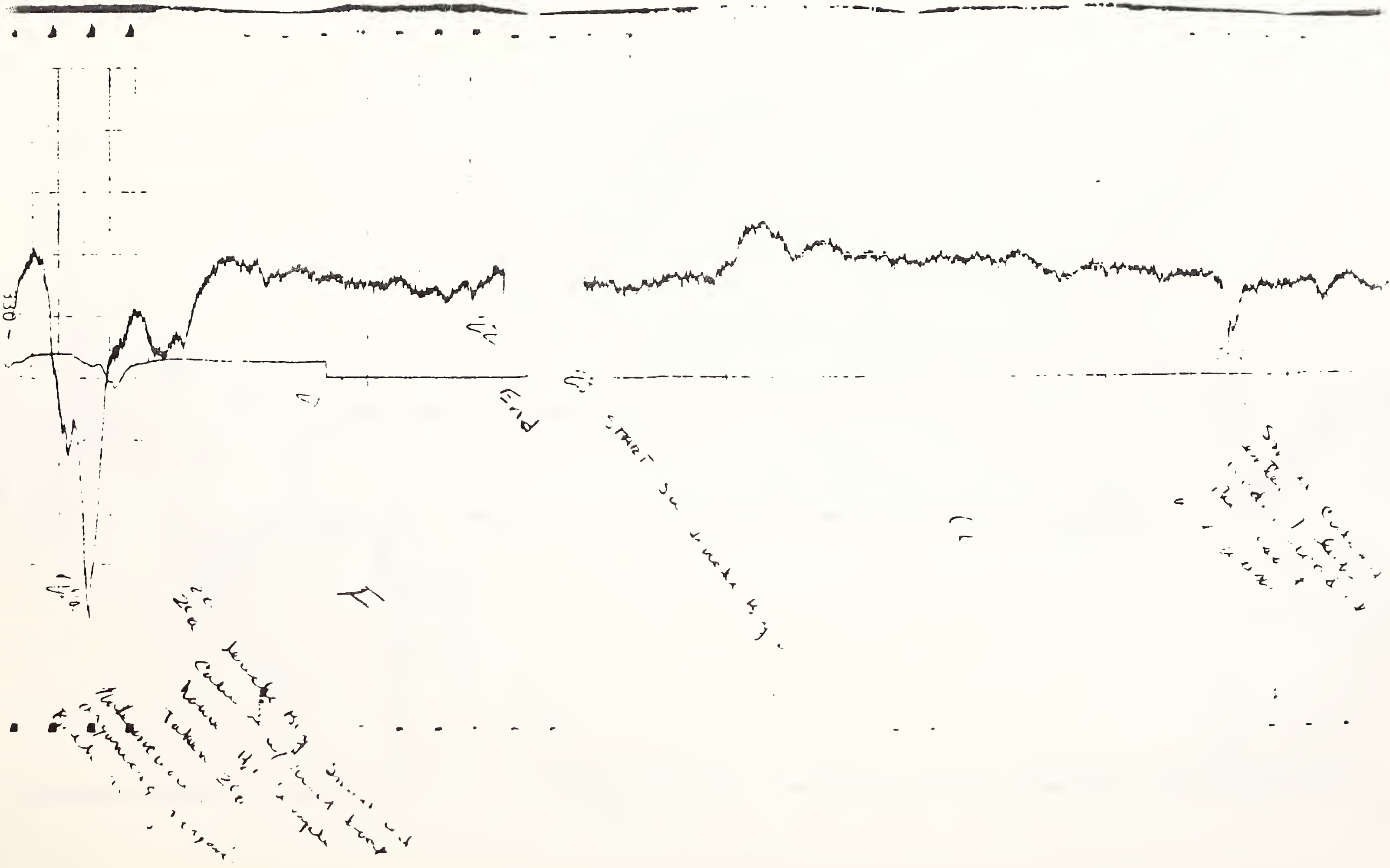


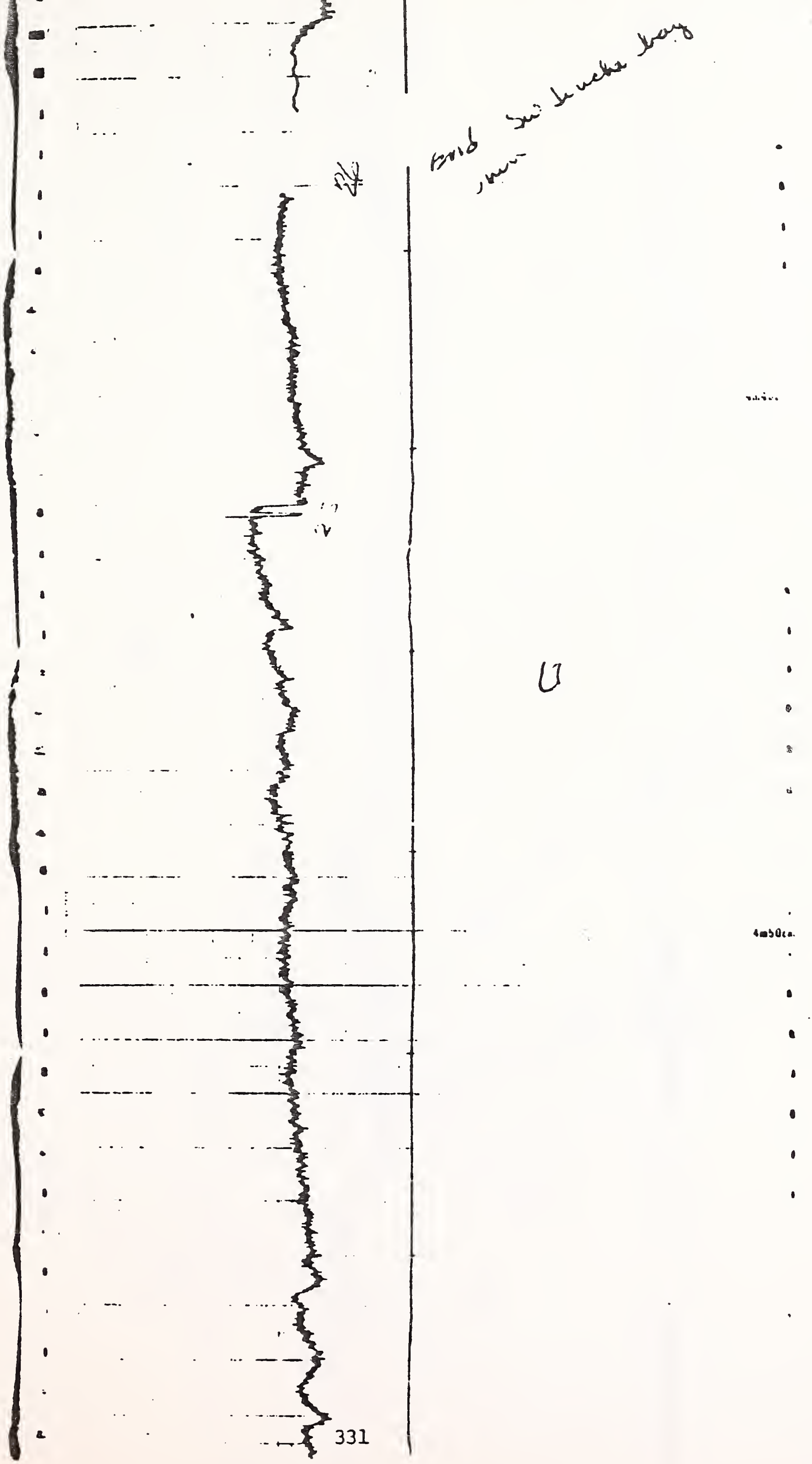
Restart Dentons MARINA
South c Lenache Bay (in MARINA)
10 knots

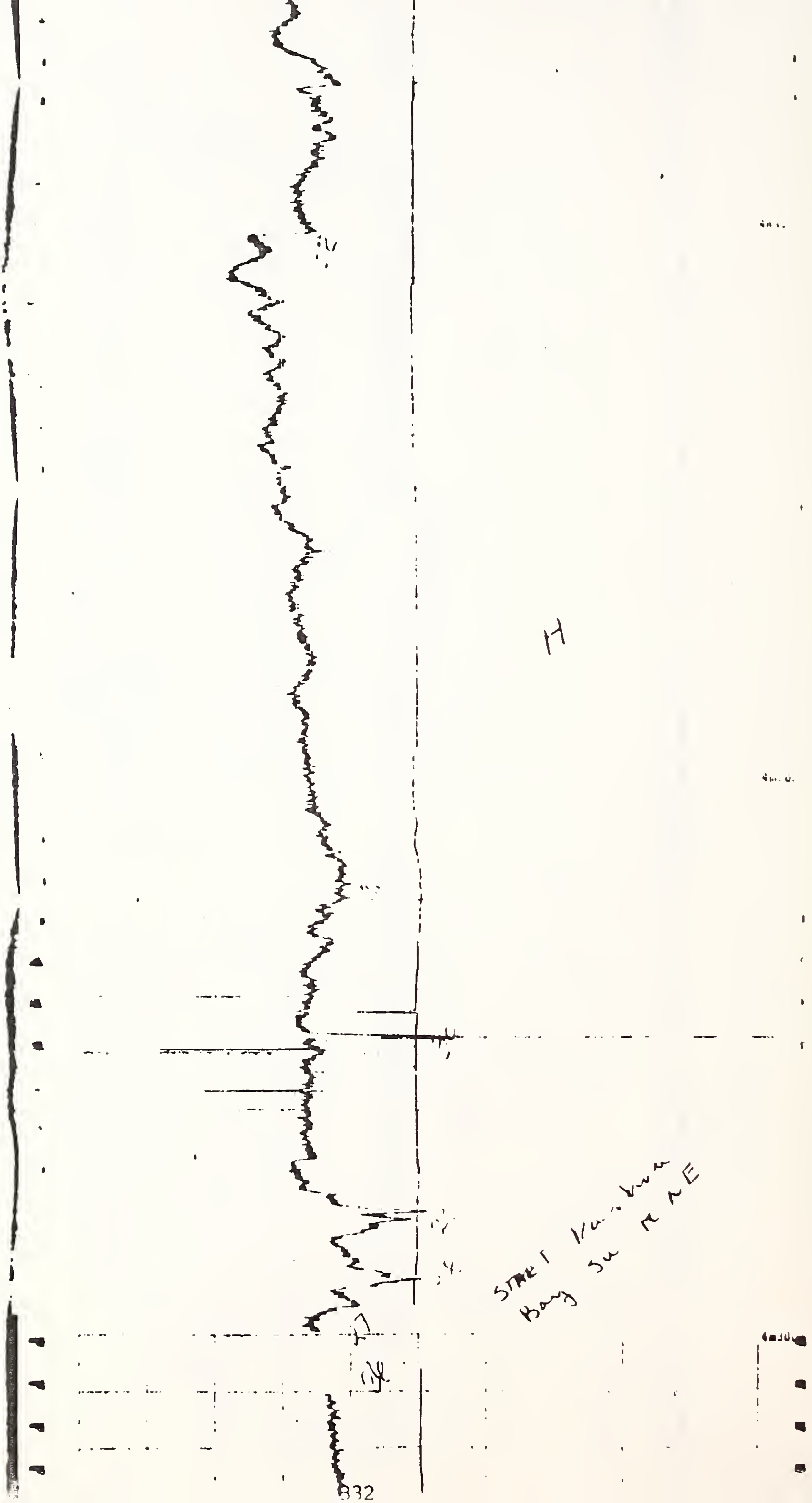
Increase in both organics & inorganics (small)
13' house

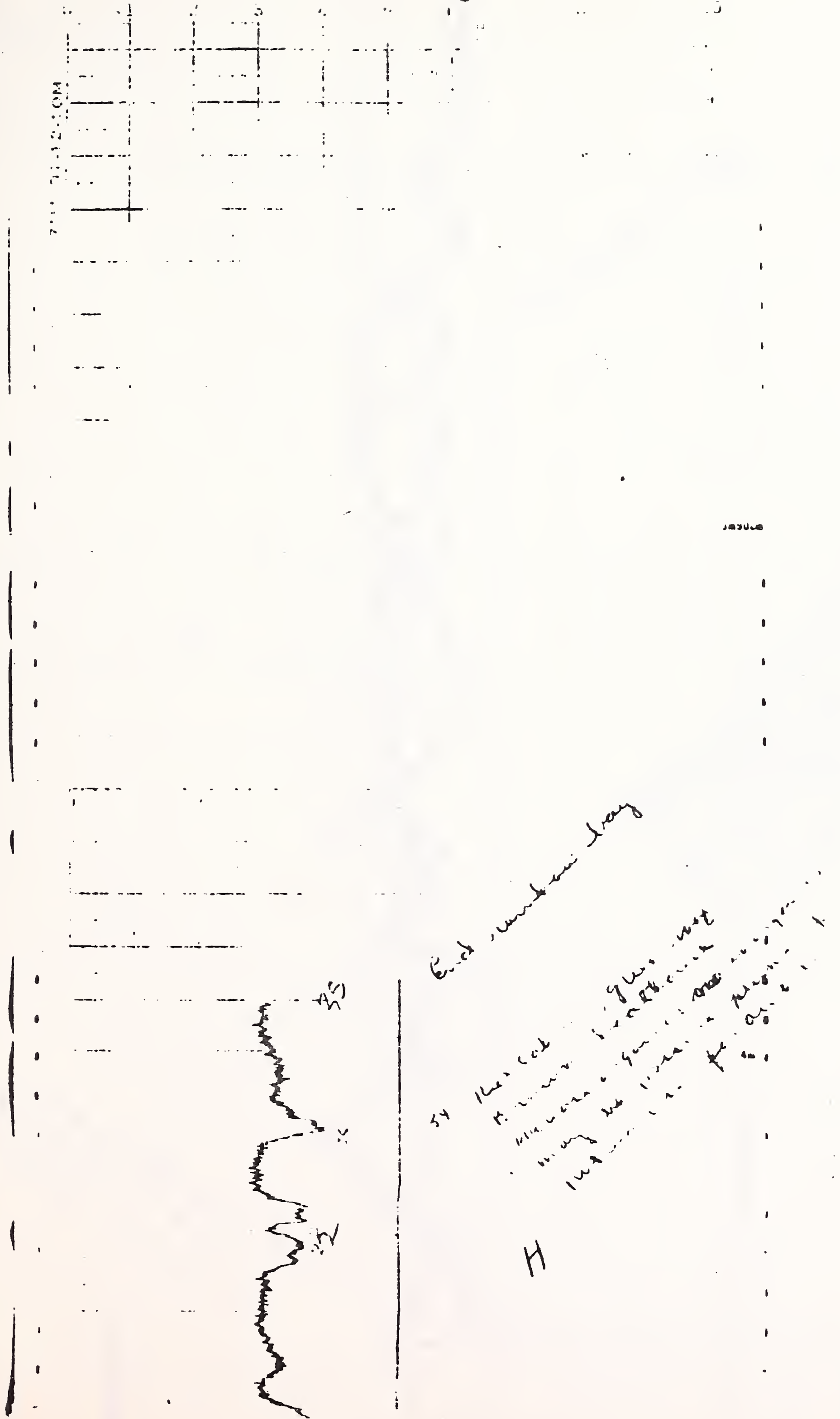
START Dentons
MARINA NORTH going
South

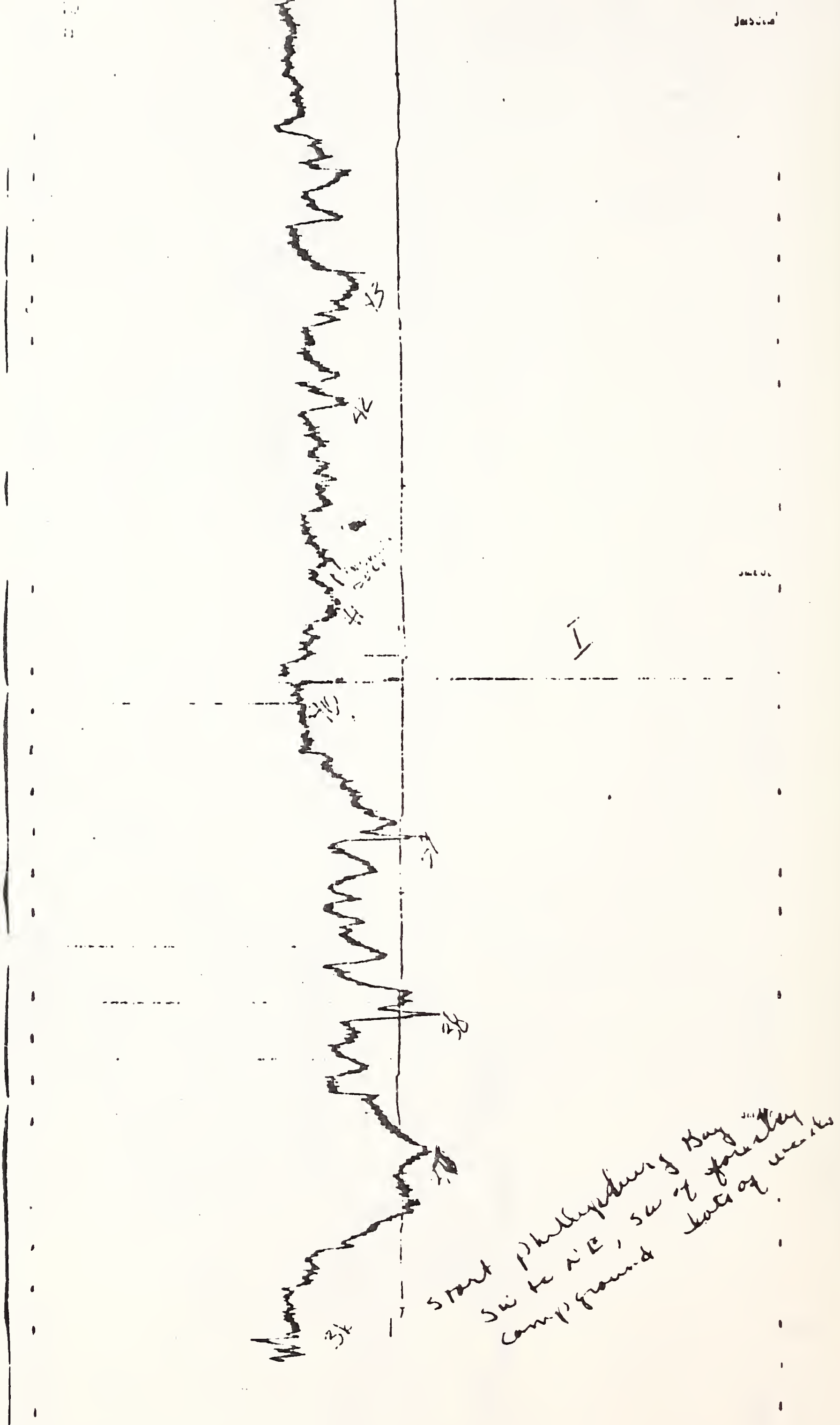

Start [illegible] north [illegible]
F
19
17
End Denuders Mode [illegible]
rezero organics and inorganics channels after [illegible] winds
17
E

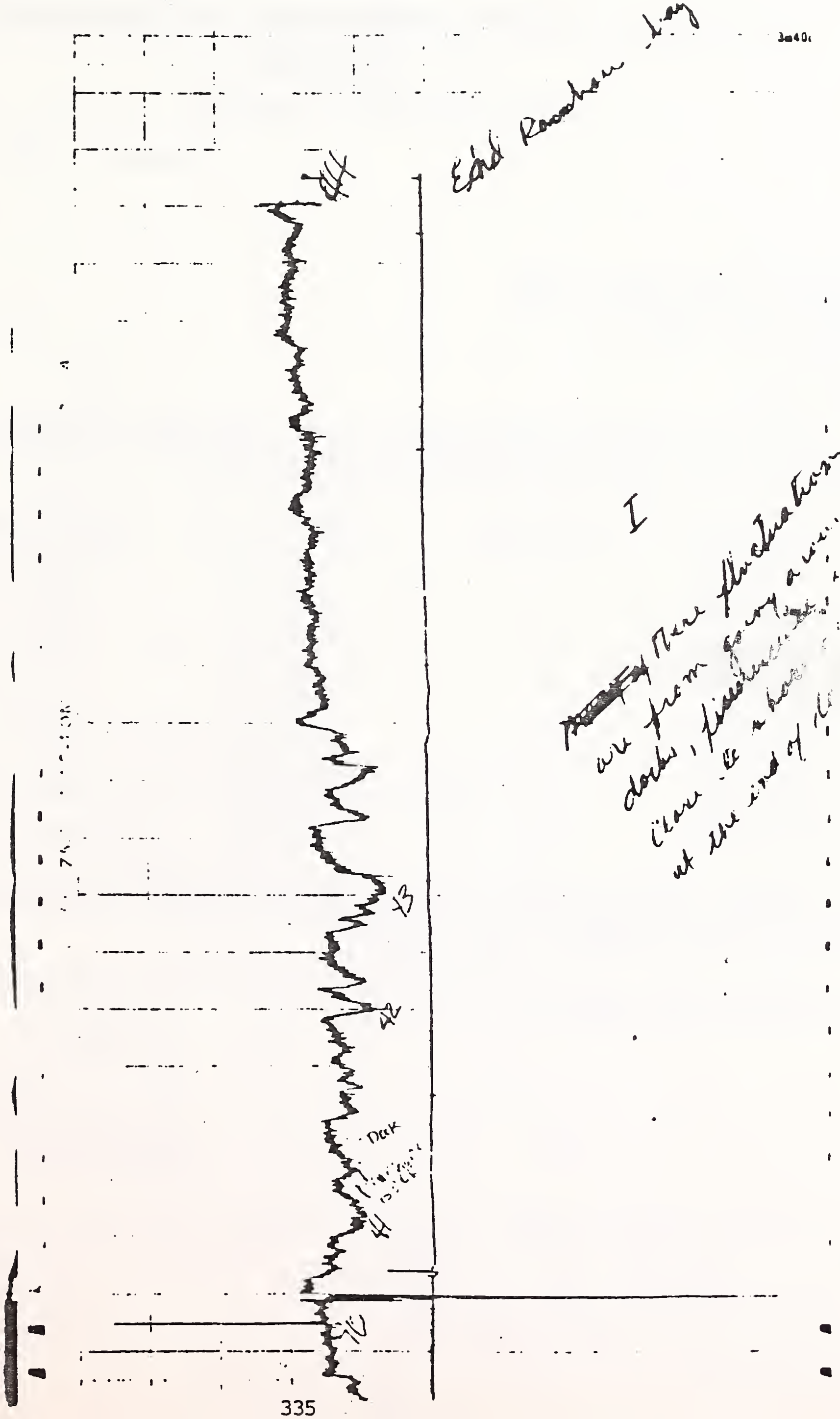

330 -
End
START
F
2c
2ca
Taken 2ca

End [illegible]
U
4m50cs


H
START Hanauma
Bay SW to NE


35
End [illegible] day
54 Recal [illegible] glass [illegible] not
H


43
42
I
38
34
Start Phillipsburg Bay
SW to NE, SW of Forestry
campground [illegible]



These fluctuations are from going a[illegible] docks, fire[illegible] close to a house [illegible] at the end of the [illegible]

APPENDIX 7.

MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY
BUTTE, MONTANA 59701

WATER MICROBIOLOGICAL LABORATORY

September 1, 1981

Paul Garrett
Georgetown Clean Lakes Project
First Security Bank, Room 310
Anaconda, MT 59711

Mr. Garrett:

Here are the results from your nine samples collected at Georgetown Lake on August 26, 1981. These samples were collected between noon and 3:00 p.m. and received in our laboratory at 4:00 p.m. of the same day.

Our Number	Your Number	Fecal Coliform	Fecal Streptococcus
81-B-0958	1	4/100 ml	< 2/100 ml
81-B-0959	2	16/100 ml	< 2/100 ml
81-B-0960	3	< 2/100 ml	< 2/100 ml
81-B-0961	4	26/100 ml	< 2/100 ml
81-B-0962	5	16/100 ml	< 2/100 ml
81-B-0963	6	8/100 ml	< 2/100 ml
81-B-0964	7	< 2/100 ml	< 2/100 ml
81-B-0965	8	110/100 ml	< 2/100 ml
81-B-0966	9	< 2/100 ml	< 2/100 ml

As only one sample bottle was collected for each site the maximum dilution I could filter was 50 milliliters; this explains the < 2/100 ml results which means there were zero colonies in a 50 ml sample.

Thank you for utilizing our laboratory and let us know if you need more sample bottles for future analyses.

Sincerely,

Deanna Anderson

Deanna Anderson
Microbiologist

APPENDIX 8.

Name ____________________
Time ____________________
Date ____________________

FIELD DATA FORM

Approximate age of structure:

0 - 5 years
6 - 10 years
11 - 20 years
20 - 40 years
40+ years

Lot size:

Less than ½ acre ____
½ to 1 acre ____
1 to 2 acres ____
2+ acres ____

Distance to lake shoreline

____ 100 yds. or less
____ 100 yds. - 400 yds.
____ 400 yds. - ½ mile
____ ½ mile to 1 mile
____ 1 mile +

Section (as shown on map) ____

Use:

Permanent residence ____
Recreational residence ____

If recreational residence, please give the estimated number of days occupied during each period (your best guess)

2 June - 1 September ____
2 September - 1 December ____
2 December - 1 March ____
2 March - 1 June ____

Average Number of Occupants During Use:

2 June - 1 September ____
2 September - 1 December ____
2 December - 1 March ____
2 March - 1 June ____

Well Information:

Depth: Less than 20   20 - 30   31 - 50   51+

Septic System:

Type: Septic Tank/Drain Field ____
Cesspool ____
Dry pit (outhouse) ____
Unknown ____

Age of Septic System:
0 - 5 years
6 - 10 years
11 - 20 years
21 years+

Size of Septic Tank ____
Unknown ____

When last pumped ____
Unknown ____

Ownership:

Ken

APPENDIX 9.

MT Lab #3447

UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

REPORT OF ANALYSIS

1. SAMPLE NO. EPA Slag Proj #3
2. DATE COLLECTED 5/9/80
3. REGION VIII
4. EPA REG. NO. N/A
5. ESTABLISHMENT NO. N/A

6. DESCRIPTION OF SAMPLE App. ½ pound of slag in a plastic bag

7. NAME AND ADDRESS OF ESTABLISHMENT WHERE SAMPLE WAS COLLECTED *(Include ZIP code)*

[illegible]

Anaconda slag that is used on road surfaces near Georgetown Lake

8. PRODUCT NAME
Slag for heavy metal analysis and leachat
testing

9. LOT OR CODE NUMBER(S)
N/A

10. NAME AND ADDRESS OF PRODUCER *(If different from 7 above)*
N/A

11. RESULTS OF ANALYSIS

	1	2	3	Blank
Sample weight	5.363 g	5.041 g	5.794 g	--
pH 1 hour after addition	6.2	6.3	6.2	6.6
pH 1 week after addition	6.5	6.5	6.4	6.6
pH 1 month after addition	6.8	6.8	6.8	6.6

Element	1	2	3	Average
Fe	0.30	0.56	0.15	0.33
Zn	0.11	0.15	0.15	0.13
Cu	0.34	0.67	0.26	0.42
As	0.024	0.045	0.021	0.030
Pb	0.037	0.077	0.025	0.046
Cr	0.007	0.007	0.010	0.008
Cd	0.0034	0.0039	0.0026	0.0033
Ag	<0.0010	<0.0010	<0.0010	<0.0010
Se	<0.020	<0.020	<0.020	<0.020
Hg	<0.00001	<0.00001	<0.00001	<0.00001

The above results are in mg/L for 5 g in 50 ml. Results are corrected to a 5 g weight. The amount present in the blank (if any) has been subtracted.

Analyst: 6/19/80

Harry Howell, Chemist III

12. LABORATORY COMMENTS

Approximately 5 g of sample was weighed into each of three 125 ml erlenmeyer flasks. To each of these flasks and to a fourth (to serve as a blank) 50.0 ml of double deionized water was added. The flasks were swirled well and allowed to sit for one hour. The pH of all four was then measured and recorded. The flasks were then covered with parafilm and allowed to sit for one week with swirling daily. After one week the pH of the solutions was measured and erecorded. The flasks were covered and allowed to sit until one month had passed from the addition of the water. The flasks were swirled daily during this period. At the end of the one month period, the pH of the solutions was measured and recorded. The solutions were then filtered through glass wool and analyzed using atomic absorption.

13. SIGNATURE OF LAB SUPERVISOR Lynn Hageman, Chemist IV
14. LABORATORY Montana
15. DATE 6/19/80

EPA Form 3540-5 (Rev. 5-76)

PREVIOUS EDITIONS ARE OBSOLETE.

ERB SLAG (PIT)	%	%	%	Oz Per Ton		%	%	%	%	%	%	%	%	%	%	%		
	Zn	Pb	Cu	Ag	Au	Insol	SiO2	Fe	S	CaO	Al2O3	As	Bi	Sb	Ni	Se	[illegible]	F
NUARY	3.96	.09	.62	.14	.0013		38.1	32.6	.7	7.2	4.8	.17	.021	.048				[illegible]
BRUARY *			.57	.10	.0010		38.1	32.4	1.0	6.2	4.6	.18	.005	.044				1.8
RCH	3.70	.02	.52	.08	.0007		38.0	34.6	.5	4.8	4.4	.14	.006	.021				2.2
RIL	3.85	.12	.69	.08	.0006		38.6	33.2	.8	5.3	4.2	.16	.006	.039				[illegible]
Y	2.80	.04	.64	.07	.0008		37.6	33.5	.8	5.9	4.3	.16	.002	.038				2.3
NE	2.10	.08	.66	.08	.0007		35.9	33.4	.9	5.6	4.7	.18	.006	.079				2.7
LY	3.00	.11	.67	.06	.0005		36.0	33.6	.9	6.0	4.4	.12	.006	.064				2.7
GUST	2.72	.08	.72	.08	.0006		35.8	37.2	1.0	5.5	3.8	.11	.006	.060				2.7
PTEMBER	3.96	.15	.76	.09	.0007		34.9	33.4	1.6	5.2	4.8	.08	.011	[illegible]				2.7
TOBER	4.13	.25	.70	.06	.0006		34.7	33.6	1.3	4.5	5.4	.13	.004	.042				2.3
VEMBER	4.12	.19	.68	.08	.0006		34.3	35.4	1.3	5.4	4.5	.10	.006	.062				2.7
CEMBER	3.30	.12	.72	.09	.0006		34.4	35.0	4.4	5.5	5.2	.17	.008	.063				2.3
NUARY	3.42	.34	.62	.06	.0006		35.5	34.3	1.2	5.6	4.7	.13	.008	.045				[illegible]
BRUARY	2.66	.10	.73	.07	.0005		35.9	34.7	1.1	5.3	4.1	.14	.009	.052				2.3
RCH N.S.																		
RIL	2.00	.07	.58	.05	.0003		36.4	35.3	.9	6.3	4.7	.09	.002	.030				2.7
	2.29	.07	.59	.02	.0004		35.4	33.7	.6	6.4	5.1	.15	.014	.042				4.6
E	1.76	.11	.68	Tr	.0004		34.3	35.5	.8	6.8	4.9	.14	.028	.044				5.5
*	2.57	.24	.82	.06	.0004		33.7	35.6	1.2	5.7	4.6	.14	.009	.038				3.3
ST	3.82	.28	.97	.13	.0011		34.2	34.2	1.1	5.8	5.4	.16	.022	.051				2.4
EMBER	4.06	.24	.72	.09	.0009		35.4	33.8	.9	5.0	5.0	.17	.004	.043				1.8
OBER	4.73	.24	.69	.08	.0006		37.7	32.7	1.1	4.9	4.9	.19	.010	.052				3.1
MBER	4.87	.36	.58	.06	.0005		37.0	32.2	1.0	4.6	4.5	.15	.006	.041				3.8
BER	4.33	.30	.66	.08	.0005		37.1	33.2	.9	4.6	5.0	.18	.010	.062				3.0

APPENDIX 10. Prior Slag Analysis, Anaconda Company, 1974-1979.

APPENDIX 11.

REPORT OF ANALYSIS

DEPARTMENT OF CHEMISTRY STATION MONTANA STATE UNIVERSITY BOZEMAN, MONTANA 59717

REPORT TO: Clean Lakes Project
Attn: Paul Garrett
Courthouse, Philipsburg, MT 59858

DATE: December 3, 1982

INVOICE NO. 1994

*Analyses performed on air dry basis.

Sample No.	Sample Description	ARSENIC ug/g (ppm)	SELENIUM ug/g (ppm)	CADMIUM ug/g (ppm)	COPPER ug/g (ppm)	ZINC ug/g (ppm)	MERCURY ug/g (ppm)		
1994-1	#1	2.2	0.06	0.13	3.8	7.4	<0.02		
1994-2	#2	17	0.11	0.49	12	27	0.02		
1994-3	#3	17	0.12	0.58	15	22	<0.02		
1994-4	#4	1.7	0.11	0.23	7.8	17	<0.02		
1994-5	#5	26	0.12	0.43	14	22	<0.02		
1994-6	#6	20	0.15	0.70	14	21	<0.02		
	QUALITY CONTROL								
1994-5	Repeat Analysis	26	0.13	0.41	14	21	0.02		

Analyses of National Bureau of Standard's
Standard Reference Material 1571--Orchard Leaves

Element	Certified Value	Analysis Result
Arsenic	10 ± 2 ug/g	10 ug/g
Selenium	0.08 ± 0.01 ug/g	0.05 ug/g
Cadmium	0.11 ± 0.01 ug/g	0.13 ug/g
Copper	12 ± 1 ug/g	11 ug/g
Zinc	25 ± 3 ug/g	28 ug/g
Mercury	0.155 ± 0.015 ug/g	0.15 ug/g